Improved Distributed Generations Models and its Optimal Placement and Sizing in Distribution System with Application in Smart Grid

By

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DEDICATION

I dedicate this work to Almighty God.

DECLARATION

I, Abdurrahman Shuaibu Hassan, hereby declared that this doctoral research thesis is an authentic record of my work carried out in the University of Johannesburg, South Africa and has not been submitted elsewhere for academic credit. This research work contains my own idea, graphics, figures and results except were reference is clearly made to another's work.

Signed… …… Date…03-09-2020

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ABSTRACT

The needs to reduce pollutant gas emissions and increase energy consumption have led to an increase in installation capacity of renewable energy sources and energy storage system (ESS). Nowadays, electrical and energy engineering have to face a new scenario in which small distributed generation (DG) sources and dispersed energy-storage devices have to be integrated together into the electrical grid. This thesis presents a detailed improvement in allocation of distributed generation in power system to reduce the challenges due to poor allocation and sizing of power generators. The first part of the thesis present vast choice on the current diversity of optimization methods applied to the aspect of planning and integration of renewable-based and the major objective is to explore various factors affecting the DG planning, optimization algorithm, objectives, decision variables employ and models applied. The result achieved shows that meta-heuristic and hybrid optimization techniques are observed to be more suitable for a large and complex system as they guarantee optimum solutions to both single and multi-objective problems. The second part of the thesis presents a multi-objective optimization algorithm for optimal placement and sizing DG units for reducing power losses and boosting voltage profiles using BPSO-SLFA. This improved algorithm is tested on both standard IEEE 33 and 66 buses system, the mathematical models are promising in minimizing losses, improvement in voltage profiles as well as cost saving in various distribution system. Results obtained shows that this optimization algorithm for the selected parameters are performing better than the ones compared in literatures in term of the objective. The third part of the thesis focuses on designing a new mathematical model water energy and food algorithm (WEFA) for investigating the size of this renewable energy (Wind, solar and gas turbine) for optimal sizing and placement of DG in radial distribution system with the aim of minimizing real, reactive power losses and emissions produced during the application of these conventional sources system. A probabilistic solution generates a number of solutions for the whole WEFA hybrid DG, thereby providing optimal solution to minimize energy losses. The simulated results are tested on IEEE 33-bus system and prove its effectiveness in optimal allocation of solar, wind and gas turbine will minimize real, reactive power losses as well as reduction in emission. The constraint handling techniques have been successfully implemented in conjunction with multi-facts devices STATCOM and UPFC for providing best solution for scenarios of multi-constrained problem of the optimal power flow. The simulation results are validated on standard IEEE 39-bus test system, the outcomes attained are related with the existing techniques and shows great improvement in terms of the objective function. In addition, studies on secure communication for IOT based smart grid to preserve the data from unauthorized users during transmission for effective securely mechanism in IOT based smart grid using Instant Encrypted transmission was studied. The final chapter of the thesis concludes with potential direction future works on optimization in smart grids.

Keywords: Distributed Generations, Water food and energy algorithm, Distributed energy resources, multi-objective optimization, wind power, solar photovoltaic, Internet of things, smart grid, smart meter.

LIST OF ABBREVIATIONS

DG	Distributed Generation
WEFA	Water, Energy and Food Algorithm
DA	Dragonflies Algorithm
DER	Distributed Energy Resources
DN	Distribution Network
LSF	Low sensitivity Factor
CVD	Cumulative Magnitude Voltage Deviation
PLD	Power Loss Index
PLMAX	Maximum Power Loss reject
PLMIN	Minimum Power Loss reject
RES	Renewable Energy Sources
PV	Photo-Voltaic System
CP	Coefficient of Performance
g	Generator efficiency
Nb	Gearbox efficiency
Ds	Distribution System
PDF	Probability Distribution Function
S	Solar Irradiance
Fb	Beta Distribution

FF	Fil Factor
IP	Current Parameters
VP	Voltage Parameters
N	Total Number of PV Modules
BPSO-SLFA	Binary Particle Swarm Optimization and Shuffled Frog Algorithm
GWO	Grey Wolf Optimization
OPF	Optimal Power Flow
IEEE	Institute of Electrical Electronics Engineering
HAS	Harmony Search Algorithm
CSA	Cuckoo Based Algorithm
SG	Smart Grid
IOT	Internet of things
IETS	Instant Encrypted Transmission Based System Security
PDR	Packet Delivery Ratio
RMS	Root Mean Square Value
ICT	Information Communication Technology
MITM	Man-In-The-Middle
DOS	Denial of Service
AMI	Advanced Metering Infrastructure
SM	Smart Meter

KGC	Key Generation Center
N	Detection Result
CP	Certification Parameter

LIST OF PUBLICATIONS

1. Abdurrahman Shuaibu Hassan, Yanxia Sun & Zenghui Wang., 2020. Optimization techniques applied for optimal planning and integration of renewable energy sources based on distributed generation: Recent trends. Cogent Engineering, 7:1, 1766394.

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5. Abdurrahman Shuaibu Hassan, Yanxia Sun & Zenghui Wang., 2020. An Effective Placement For optimal power flow with inclusion of multi-facts devices. (Submitted).

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In modern-day power systems, minimization of power losses and enhancements in voltage profile are two of the critical areas of interest for power quality enhancement. The existence of these factors affecting power system networks is due to transmission line contingencies(Tiwari and Ghatak, 2017). There are a variety of problems related to distribution systems that need the attention of planning engineers to maintain system reliability and stability. A High R/X ratio of the distribution line results in huge power losses and has a more significant impact on the voltage stability of the system. Generally, at the distribution level of 13% of the generated power is wasted as losses of line. The increment in line losses takes place as the loads are inductive working at low power factors. These small power factor inductive loads lead to voltage instability in the power system network. Power system researchers have tried to rectify the distribution system problems related to line losses, voltage profile, power losses, energy losses, voltage stability based on the placement of DG's. In a power delivery system, there is a need for enhancing the power transfer capability which is fulfilled by the use of compensation devices thereby reducing the flow on overloaded lines which in turn increases the transfer capability of the existing transmission and distribution networks (Tiwari and Ghatak, 2017). Because of the mutual and detrimental interactions between the compensating devices, the problem of determining the suitable locations for device placement becomes a question of great significance for planning engineers. Therefore, power engineers are developing evolutionary methods to identify the weak areas/zones in the power system network so that optimal allocation of the FACTS [Flexible Ac Transmissions] devices is made possible which can be advantageous as it would be computationally inexpensive and saves time (Tiwari and Ghatak, 2017)

The needs to reduce pollutant gas emissions and the increasing in energy consumption have led to an increase in installation capacity of renewable energy sources and energy storage system (ESS). Nowadays, electrical and energy engineering have to face a new scenario in which small distributed generation (DG) sources and dispersed energy-storage devices have to be integrated together into the electrical grid. The new electrical grid, also named smart grid (SG), will deliver electricity from suppliers to consumers using digital technology, thus reducing cost and increasing reliability and transparency. As the impact of geography, climate, weather and other external factors, the output energy of renewable energy sources is intermittent and unpredictable; this will cause the complexity of energy exchange between the DG sources, ESSs and load. Furthermore, the user can purchase electricity from the grid and can also sell surplus energy of the own DG sources to the grid, which will increase the complexity of energy exchange between the distributed sources, ESSs and load in the micro grid (MG) and the main network (M. Chen *et al.*, 2017).

Distributed generation is an electric power source connected directly to the distribution network or customer side of the meter. In simple terms, it is a small-scale electricity generation. The definition of distributed generation takes different forms in different markets and countries and is defined differently by various agencies. International Energy Agency (IEA) defines Distributed generation as generating plant serving a customer on-site or providing support to a distribution network, connected to the grid at distribution-level voltages. CIGRE defines DG as the generation, which is not centrally planned; it is not centrally dispatched at present; it is usually connected to the distribution network; it is smaller than 50–100 MW. Other organization like Electric Power Research Institute defines distributed generation as generation from a few kilowatts up to 50 MW.

In general, DG means small scale generation. There are several DG technologies available in the market today and few are still in the research and development stage. Some currently available techniques are reciprocating engines, microturbines, combustion gas turbines, fuel cells, photovoltaic, and wind turbines. Each one of these technologies has its benefits and characteristics. Among all the DG, diesel or gas reciprocating engines and gas turbines make up most of the capacity installed sofar. Simultaneously, new DG technology like a micro turbine is being introduced and an older technology like the reciprocating engine is being improved. Fuel cells are the technology of the future. However, there are some prototype demonstration projects. The costs of photovoltaic systems are expected to falling continuously over the next decade. This all underlines the statement that the future of power generation is DG. Supplying peaking power to reduce the cost of electricity, reduce environmental emissions through clean and renewable technologies (Green Power), combined heat and power (CHP), high level of reliability and quality of supplied power, and deferral of the transmission and distribution line investment through improved loadability are the primary applications of the DG. Other than these applications, the primary application of DG in the deregulated environment lies in the form of ancillary services. These ancillary services include spinning and non-spinning reserves, reactive power supply and voltage control, etc.(Acharya, Mahat and Mithulananthan, 2006).

The term distributed generation (DG), otherwise known as embedded generation (EG) or decentralized generation (DG), in some quarters is generally defined as any source of electric energy of limited capacity that is directly connected to the existing network on the customer side of the meter. The current system could be a distribution network or a sub-transmission network. At present, there is no consensus on what precisely the rating of DG as well as the voltage level at the point of universal coupling (PCC) to the grid should be. The definitions of these two parameters rather vary from country to country and from one research group to another. For example, while Portugal pegs the capacity limit of DG to 10 MW that can be connected at any voltage level, Austria defines DG as an electric energy source of up to 10 MW to be connected at the MV level. In France, DG is defined in a capacity as greater than 40 MW and connected at 225 kV voltage level. Spain allows the DG capacity to go up to 50% of the feeder capacity(Tiwari and Ghatak, 2017). So far, Australia has been able to practically install the largest size of 130 MW DG at 132 kV on its power grid, while Denmark allows the utility to decide the voltage level of connection for DG units ranging from less than 2 MW to greater than 50 MW(Akorede *et al.*, 2011).

The distributed generation (DG) is characterized by the installations of small sources in different locations of the system, trying to be as close to the final consumer to get benefits in power quality. In the last years, the increase of DG installation brought up different issues in the energy industry, scientific community, economic and environmental policy management. This form of power generation has been contributing to the development of new green supplies, which is a way to diversify energy sources from the main hydro and thermal power. The impact of DG on a smart grid is a big challenge for power systems and mainly when the integration of DG is based on renewable energy sources (RESs). The DG power injection may change the power flow course in the distribution feeder. The DG allocation and sizing are decisive to keep acceptable levels in the power quality of the electrical power system because it improves the power quality reducing loss and distribution cost. On the other hand, the lousy allocation may cause undesirable effects. Therefore, it is essential to use an optimization method capable of obtaining the best possible solution. In the distribution level, the micro-grids may be connected to the distribution feeder and receive some ancillary energy benefits in case the DG produces more energy than the owner uses. Currently, many optimization techniques are being implemented to find out how to integrate the DG with the power system more efficiently using adequate power injection to improve the power quality. In this context, this paper proposes a novel optimization approach that considers a 24-hour power load to locate and size the DG (Angarita *et al.*, 2016). In this research, such allocation problems are handled by designing a new mathematical algorithm capable of allocating and sizing DG in an appropriate location with the technical objectives of minimizing power losses, boosting voltage profile, voltage deviation minimization, fuel cost minimization, and voltage stability.

1.2. Problem Statement

Increasing energy demand is a significant challenge in the future electrical power system as it is a critical factor for the development of the economy. It is estimated that the generation of power increases by 93 percent during the period 2010-2040 (Kumawat *et al.*, 2018). The increasing load growth can be supplied by expanding the existing substation. Moreover, regulatory environment and technological innovations under the forthcoming economy have resulted in a renewed interest in the Distributed Energy Resources (DER) such as Distributed Generators (DGs) and Shunt Capacitors (SCs), especially in the smart grid paradigm.

Therefore, engineer planners have filled the gap between supply and demand by renewable and non-renewable DERs. Integration of renewable source has reduced the dependency on fossil fuel; moreover, reduces the pollutant contents in the environment (Kumawat *et al.*, 2018). In the electricity market scenario, various types of famous DER technologies have been used and some are still immature and under the developing stage (Kumawat *et al.*, 2018). These technologies are small hydropower generation, photovoltaic, natural gas engines or reciprocating diesel, microturbines, fuel cells, and wind turbines. The DGs are available in modular units, lower capital costs, characterized by smaller size, and shorter installation time (Kumawat *et al.*, 2018). The conventional power system has turned into an active distribution system after the interconnection of the DERs. Thus, DER planning is essential to minimize the future reconfiguration of distribution service.

The attractive rate of burning up fossil fuel has dragged the world in the crucial phase from which it is fast approaching the peak of fuel expenditure especially oil and gas. This impulsive stage has begun the turning up of researcher's efforts towards the investigation of alternatives for endangered conventional energy resources. However, DG deployment, considered as part of the solution to the world's energy crises is changing the context in which electric power systems are conventionally operated and regulated (Jain *et al.*, 2017). The successful and beneficial DG deployment trepidation leads to an obligation of re-examination of both. These tiny technologies, which were previously been overlooked by governments and power system operators due to limited energy extracting methodologies are now coming back into enthusiasm. The tremendous growth in population and available conventional energy sources shows an inversely proportional ratio. This adverse circumstance provides a vent for the search for new energy sources (Jain *et al.*, 2017).

The main hurdles are implementation, installation, Sizing, Location, type of DG, and reliability of the DG insertion strategies as well as techniques. Thus, a lot of researches are undergoing hard to establish better and revenue proper procedures to exploit all possible benefits of DG(Jain *et al.*, 2017). The significant surge in distributed energy resources (DER), urges some utilities for modifying their business prototypes to reflect the increasing use of DER. Although numerous technologies are available focusing the execution of successful DG penetration in the system, but yet there is still a gap to be filled on the Optimal allocation of this DG, type of the DG as well as particular locations to installing this DG in the Distribution system by considering larger networks to minimize Losses, none of the existing work has presented their detailed analysis, specifically the relevant scope in DG designing and installation. Thus, the focus of this research is to Design a Mathematical Model for proper allocation, sizing as well as the type of DG in Larger Networks of the Distribution System to Minimize the Problem of allocation in the Distribution System. Thus, the use of this algorithm is a promising solution to the problem identified above.

1.3. Aim of the Research

This research work proposes to create a new mathematical model for optimal allocation of DG in Larger Networks in the Distribution system as an alternative to the existing System to evaluate, improve, and understanding the performance of this new Algorithm to boost DG operation.

1.4 Objectives of the Research

1). To develop/construct a mathematical model for the Allocation of DG in the Distribution System for Optimal power flow control in the DG Using (Water, Energy, and Food) Algorithm.

2). To identify optimal Parameters or Parameters of Optimization of Power DG allocation in the Distribution System using the BPSO-SLFA Algorithm.

3). To develop a mathematical model with the inclusion of Multi facts devices with the injection of systems power flow and elevate the power flow.

4). To develop optimal network parameters or parameters of optimization for secure communication for IoT based smart grid against attacks.

5). To test the Model, develop in (1, 2, and 3) above with two or more existing ones.

1.5 Research methodology

In this research work approaches based on single and multi-objective optimal allocation and sizing renewable DG based source in distribution system configurations was investigated, and their pictorial representation are shown in following chapters of the thesis. For each outline, a joint mathematical model formulation of both single and multi-objective is developed. The performance of the improved system would be compared with other system based on selective objectives.

Mathematical modeling problems would be formulated to accommodate the constraints variables based on selected renewable energy sources (Solar, wind and fuel cell). The models developed will be specified and entered in mat power, and the data for the optimized system were generated from literature and the solve optimization problem on pc with intel core is run on a Matlab 2018.

1.6 Research Contribution

The main contributions of this research are summarized as follows:

- The incorporation of optimal power flow with the inclusion of multi-facts devices to provide the best solution to the active power losses, voltage stability, fuel cost, and voltage stability index using GWO-BSA was developed to the system at an optimum position.

- The development of a novel hybrid strategic approach based on the BPSO-SLFA algorithm for optimal placement and sizing of DG to minimize power losses and boost voltage profiles is properly studied.
- Joint mathematical formulation model for determining the size of the renewable energy based on DG (Wind, Solar, and Fuel cell), to extract the exact location to fix our DGs within the distribution network system to minimize losses was adopted.
- A robust mathematical model for secure communication for IoT smart Grid is developed using an Instant Encrypted Transmission System (IETS) to secure the data transmission from the Smart Grid to the user is developed.

1.6 Organization of the Thesis

The Thesis is structured as follows:

- Chapter two of the thesis deals with "Optimization techniques applied for optimal planning and integration of renewable energy sources based on distributed generation: Recent trends", it gives a detailed description of the literature survey in the proposed area.
- Chapter 3 is "Multi-objective for optimal placement and sizing DG units in reducing loss of power and enhancing voltage profile using BPSO-SLFA".
- Chapter 4 of the thesis is "Water, Energy & Food Algorithm with optimal allocation and sizing of Renewable Distributed Generation for power loss minimization in distribution system".
- Chapter 5 presents optimal power flow with the inclusion of multi-facts devices for providing the best scenario for the multi-constrained problem of the optimal power flow. A hybridized GWO-BSA was implemented to elevate the power flow in the system and the developed algorithm is tested on the IEEE-39 standard bus system.
- In Chapter 6 a robust mathematical model for secure communication for IOT based Smart Grid is developed using an Instant Encrypted transmission-based security system (IETS) to secure the data against malicious attack from the Smart Grid to the user. The Algorithm developed is observed to minimize power consumption for loads, packet delivery ratio (PDR), and the delay has significantly reduced as compared to the other system under study.

- Chapter 7 concludes the thesis and gives direction for future scope research.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Traditional power generation is currently unable to satisfy the ever-increasing worldwide demand for electricity About 16% of the world's population still lives without electrical energy due to poor network construction (Report, 2017), Subsequently, a power supply system needs to accommodate these changes for a better quality of user experience ('Ekpa, T. K. 1*, Sani, S.2, Hasssan, A. S.3 and Kalyankolo, Z.4 1,Journal of the Nigerian Association of Mathematical Physics Volume 48 (Sept. & Nov., 2018 Issue), pp347-352 © J. of NAMP ON', no date). Unfortunately, Distributed generation (DG) has proven to be a feasible alternative solution in this view were electricity is produced close to the load centers. Although DGs have several environmental and economic advantages, in the distribution system, they impose various operational problems. These may include, but not restricted to, power relaying problems created by inverse power flow, the problem of voltage increase and power quality issues (Lam and Varbanov, 2011; Manfren, Caputo and Costa, 2011; Quadri, Bhowmick and Joshi, 2018). DG is a small scale electrical power generation units connected directly to the loads or consumer meter side (Hydro and Centre, 2016). Various researchers and countries have adopted a different definition for DG, (Approach, 2007) define distribution system as a failure of a digital system that has not existed in your system and can solve other unstable decisions within the given computer system. Historical background on the concept of DG was proposed by (Public, Commission and Monday, 2014), which categorized DG as a small device that allows electrical power energy to be generated by using renewable energy sources. In (Friedman, 2002), DG defined as a small modular plant place close to the load for the purpose of electricity generation and storage technologies within the grids. Ref (Martin, 2009) classified DG as a point where electricity is generated at the point of its use. The electrical power research institute (EPRI) defined DG as a few KW to 50MW (Viral and Khatod, 2012). For Details in various DG, definition see (van Gerwen, 2006; Martin, 2009; Abou El-Ela, Allam and Shatla, 2010). However, Different types of renewable energy DG technology categories were highlighted in (Østergaard, Albadi and El-Saadany, 2001; Pepermans, 2005). Many authors characterized DG as a generation connected on the distribution side that ranges from a few KW to a few tens of MW, as shown in Table 2-1 (M. H. Moradi and Abedini, 2012a; Treatment, 2015; Prakash and Khatod, 2016; Theo *et al.*, 2017). The DG capacity per year is reported to be growing from 47GW to 142GW in the period of 2000 to 2012 worldwide due to huge investment, and the total target is to reach 200GW and $206 billion by the year 2020 (Ehsan and Yang, 2018a) as shown in Figure2-1.DG has become a feasible solution to rural areas where the cost of transmission and distribution is extremely high, and this making DG more popular. In (Davis and Ieee, 2002), Comparison between distributed resources and the traditional power system in terms of transmission and distribution system, to check efficiency, losses, voltage profile, reliability, emissions, and power quality was studied and the author findings concluded that investment cost in distributed resources is lower compared to the traditional system. The technologies adopted in distributed generation comprises of a small gas turbine, fuel cells, micro-turbines, wind, solar energy, and hydro-power. Figure 2-2, shows a distinct difference between the central utility of today and distributed utility of tomorrow. In the development of traditional power plants, there are technical and environmental limitations such as fuel sourcing, global sourcing, emissions and localized pollution. Moreover, the unsafe market for fossil fuel has pushed the electricity market in searching for new sources of energy (A, Dang and Ramachandaramurthy, 2016). Adding DG to the energy scheme decreases electrical power losses to achieve greater reliability of the system (Hassan, Adabara and Ronald, 2018). However, a U-shape trajectory is presented by the DG penetration rate versus power loss. The non-optimal positioning of DG can, therefore, boost power losses and thus enhanced the voltage profile to support the permissible limit (Quezada, Abbad and San Román, 2006). However, utilities are already subjected to technical and non-technical issues, therefore an optimum placement and sizing renewable DG is required to minimize the power system losses, boost reliability and stability and enhancement of voltage profiles. Authors in this field have contested that DG capacity and locations are very important in improving the distribution system performance (Hemdan and Kurrat, 2008), and the authors finding were based on the presence of renewable DG such as (solar, wind and fuel cell), increases the load of the network system.

There are various approaches carried out in literature to find the optimal position for the integration of DG into the distribution network system. Various objective functions (Bus cumulative magnitude and voltage deviation) are developed and solved. In (Borges and Falcão, 2006), the objective function formulation is the maximization of cost-benefit of DG integration to the investment cost. The benefits were to reduce the net electrical losses and the investment cost as well as installation costs. A multi-objective technique based on genetic algorithm was studied by (Ochoa and Harrison, 2011) to determine optimal power flow and accommodate renewable energy sources by minimizing total energy losses. In (Zhao *et al.*, 2019), the objective function is to investigate the uncertainty of DGs and loads, power generation cost and environmental cost of different renewable DG integration. A multi-objective optimization problem applied based on a double trade-off procedure $\varepsilon - constrained$ approach for integration of DG to reduce cost of energy not served and cost of grid energy purchased. The proposed methodology is capable of solving of maximizing network performance by optimizing some elements like voltage quality and harmonic distortion. The effects of load model size was investigated by (Singh, Singh and Verma, 2009), based on multi-objective function using various indices. It is observed based on the model that the effects of load models can significantly disturb planning and sizing DG. Fuzzy logic-based planning by considering uncertainty modeling to incorporate the DG within the electrical power distribution is proposed in (Ganguly, Sahoo and Das, 2013), the objective was the application of a Petro-based approach for total optimization of cost of planning, reliability and risk of, constraints fully minimized. In (Hydro and Centre, 2016) analytical approach based techniques proposed for optimal sizing and sizing DG for a balanced radial system. The model identify the buses in the network to be compensated by reducing the power losses with single DG placement in DN. Growing interest in the application of DG optimization techniques deploy by the use of renewable energy sources is extended all over the globe, it is observe that one quarter of that energy is witnessed in Europe, Asia and part of united states of America (Abdmouleh, Gastli, Ben-Brahim, *et al.*, 2017). Despite the advantages derived from DG integration from renewable energy sources research shows that utilities suffer a great system loss, from inappropriate placement and sizing (Griffin *et al.*, 2000; Mithulananthan, Oo and Phu, 2004). Proper mathematical modeling optimization techniques provide solutions for boosting reliability of this utilities deployed.

Table 2-8, summarized DG technologies by bringing out benefits of each sources in terms of (emission, voltage profile, cost of packing, cost of installation, reliability improvement and power quality).

This research paper presents a vast choice on the current diversity of optimization methods applied to the aspect of planning and integration of renewable-based DG. The major objective is to focus on solving the problem of optimal placement and sizing DG from renewable energy sources. In addition, other factors affecting DG planning are reviewed and discussed in detail. This study will provide general knowledge to researchers for further exploration.

Table 2-1: Shows the different types of DG categories and ratings for future application [10–13]

S/No	Type of Distributed Generations (DG)	Capacity	DG ratings
1.	Micro-distributed generation	~ 1 W < 5 kW	Solar Technology
2.	Small distributed generation	5kw < 5000KW	Biomass, Bioenergy, fuel cell &wind turbines
3.	Medium distributed generation	5MW <50MW	Geothermal energy
4.	Large distributed generation	50MW<300MW	Hydrogen fuel energy

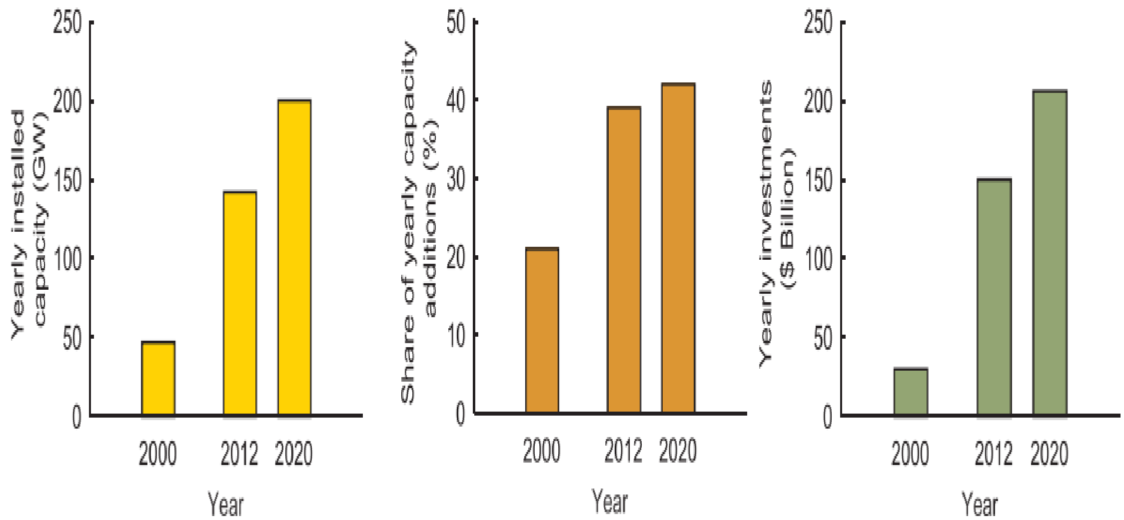


Figure 2-1: Illustrate a graph showing yearly installed capacity, share of capacity additions and investments in DG sources worldwide (Ehsan and Yang, 2018b)

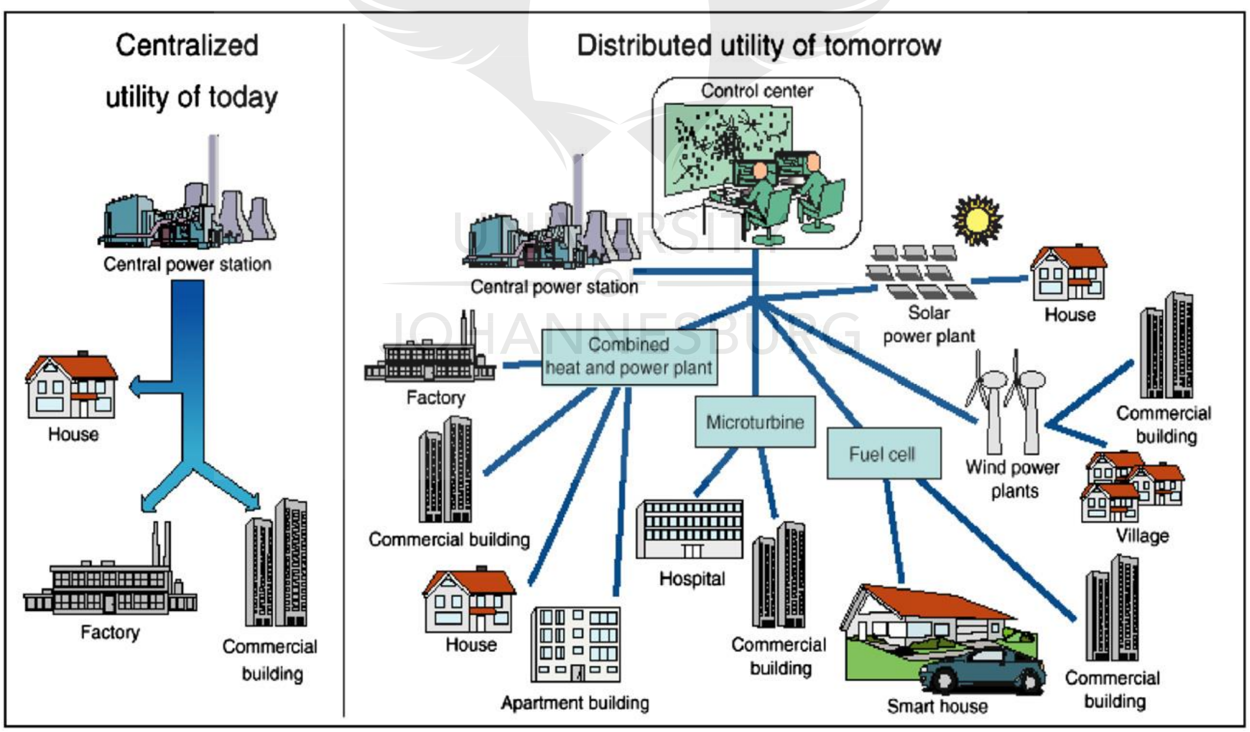


Figure 2-2: Shows. the central utility of today and distributed technology of tomorrow (Viral and Khatod, 2012)

2.2 PREVALENCE WEAKNESS IN DG GROWTH

Optimal allocation of distributed generation has received much attention recently due to its various importance. However, it becomes an exacting task in integrating the DG into an existing network system. This challenging effect arises, because the integration of DG changes the entire system behavior from active to passive. Many authors have pointed out the importance of placing DG in an optimum position. In (Tan, Hassan, Majid, *et al.*, 2013; Ugranli and Karatepe, 2013; Murty and Kumar, 2015), DG properly installed in an optimum position will enhance the voltage profile of the electrical power distribution network. If installed at the best location and the proper size, they will minimize power losses and maximization of system voltage stability (Pepermans *et al.*, 2005; Aman *et al.*, 2012; Kansal, Kumar and Tyagi, 2013; Kalambe and Agnihotri, 2014; Babu and Singh, 2015; Murty and Kumar, 2015). Ref (Lopes *et al.*, 2007), pointed out the benefits of integrating the DG by using renewable energy sources (wind, solar, biomass and so on), which regulates environmental effects like emission control. In (Allan *et al.*, 2015), review various literature on different DG technologies on how to control the emission. DG serves as an alternative source in assisting the rural side, where the cost of transmitting and distribution of power system is high see details (Karki, Mann and Salehfar, 2008). If properly installed at the proper location will relieve the issues of uncertainty loading of the feeders (Zeinalzadeh, Mohammadi and Moradi, 2015; Muthukumar and Jayalalitha, 2016, 2017). Inappropriate optimum allocating and sizing the DG can lead to a negative impact of all the advantages mentioned (Prakash and Khatod, 2016). It has become necessary to size and allocates the DG in an optimum position, since the advancement in the technology is rapidly growing by cutting various costs, boosting efficiency and enhancing the voltage profile within the power distribution network. Despite the availability and environmentally friendly of these energy sources, the institute of electrical electronics engineering (IEEE) has set various rules to follow in integrating distributed energy sources (DER) in the distribution system. Table 3 provides the IEEE 1547 series towards achieving a sustainable environment, table 4 provides voltage and frequency acceptable rate in operating DER in the distribution system. Most of the benefits of employing DG in existing distribution networks have both economic and technical implications and they are agnate. However, the major driving factors increased in penetration of DG integration issues are classified into three categories: Environmental, regulatory and economic factors.

2.2.1 Environmental aspects

In environmental aspects, the broad penetration of distributed generation in the distribution network is of major significance. DG-based fossils fuel dissipates a lot of environmental emissions and leads to unresolved issues. However, the DG implementation and only restricted measurements are characterized by a wide range of fuel energies, advanced techniques and operating patterns (Greene and Hammerschlag 2000). The utilization of fossils-based DG energy sources leads to the largest emission of Greenhouse (GHG) gas emission such as (water vapor, carbon dioxide, Nitrous oxide and Hydro fluorocarbons), which resulted in environmental concerns and climate change. Environments and creatures are affected worldwide, this has led to the search of non-polluting resources and more efficient technologies that will solve environmental problems and reduction in the price of fossil energy (Chaitusaney 2014). The integration of DG on large scale produces various types of emissions, as electricity generation is always the major contributor to these emissions. Statistics have shown that in the united states of America that electricity production from non-renewable DG sources has resulted in one-quarter of nitrogen oxide (NOx), carbon monoxide and Sulphur dioxide (SO_2) (States, n.d.). However, despite this negative environmental impact from the non-renewable energy sources, DG could have positive impacts of integrating renewable energy sources into the electrical power network which will reduce the gaseous emission mentioned above. Various literature exists on the use of renewable energy sources to reduce gaseous emission see (M. Chen and Cheng 2012; Liew et al. 2017; Di Somma et al. 2016; Cao et al. 2016; Akorede, Hizam, and Pouresmaeil 2010; Abdallah and El-Shennawy 2013). Table 2-2 and Table 2-3 are environmental standards value for pollutant and penalty emission control (M. Chen and Cheng 2012) and Table 2-7, shows potential emission reduction of Carbon (IV) oxide and electricity emission to be achieved in 2030 ([PNNL] Pratt, R.G., Balducci, P.J., Gerkensmeyer, C., Katipamula, S., Kintner-Meyer, M.C.W., Sanquist, T.F., Schneider, K.P., Secrest 2010).

Table 2-2: Shows emission characteristics of several electric generations in (g/kWh)

Technology	SO_2	NOx	CO_2	CO
Thermal power plant	6.48	2.88	623	0.1083
Micro-gas turbine	0.000928	0.6188	184.0829	0.1702
Fuel cell	0	<0.023	635.04	0.0544
Photovoltaic	0	0	0	0
Wind	0	0	0	0

Table 2-3: Shows the environmental standard value for pollutant emissions

Emission	SO2	NOx	CO2	CO
Value	0.75	1.00	0.002875	0.125
Penalty	0.125	0.250	0.00125	0.020

2.2.2 Economic aspects

DG's interconnection to the traditional electrical power system needs additional underground cable installation so that DG can be integrated into the new scheme. In addition, the incorporation of DG into the new scheme can lead to certain problems such as; voltage flicker, harmonics introduction, the inverse operation of the energy system flows and protection challenges see (Hadjsaid, Canard and Dumas, 1999; Barker and De Mello, 2002; Akorede, Hizam and Pouresmaeil, 2010), for details. Such issues must be properly addressed to achieve the maximum benefits of the reliability of the distribution system (Singh and Parida, 2017a). Summary of these challenges are better explained in table 2-6, (Zubo *et al.*, 2016).In addition to these economic benefits, DG still represents the world energy through reduction of cost, saving transmission and distribution.

2.2.3 Technical aspect

DG technical element covers a broad range of issues such as peak load shaving, excellent voltage profile, decreased system losses, enhanced system continuity and reliability, and some power quality issues that are filtered out. The total reduction in the loss of energy system may be of concern to some utilities in developing nations, as some of these utilities lose up to 20% of their complete energy generation (Singh and Parida, 2017b). The following are the technical benefits derived from DG, if positioned at an optimum location.

- The total reduction in line losses.
- Boosting system reliability and power system security.
- Increased system efficiency.

2.2.4 Regulatory policy

It appears that the creating of suitable approaches is so significant to help in the coordination of the distributed generation into an appropriate distribution system because of the nonappearance of clear legislative guidelines (Niwas, Version and Congress, 2009). Nowadays particular attention is paid in the European zone on how to tackle the effects of climate change and have a strong body that will promote the use of clean energy towards achieving secured energy (Cossent, Gómez and Frías, 2009). Table 2-4 summarized some weaknesses of DG.

Table 2-4: Shows Weakness of DG in terms of various conditions

Commercial aspect	Technical aspect	Environmental aspect	Regulatory aspect
Recovering the cost of implementation	Power quality and voltage flicker	Emission characteristics	Policy regulation
Incentive scheme	Stability and protection	Control of power plants	-
Market pool creation	The reverse flow of the power system	Power quality issues	-

2.3 Review of optimization techniques applied on DG's based on optimal placement and sizing

Optimal allocation techniques solve problems linked to sizing and appropriate positioning of DG's by enforcing various mathematical optimization objective features with many technical operational limitations, implementing distinct computational methods with the account of distinct DG kind based on power factor (PF) and multiple numbers of units. This study presents a trend on research publications since the early 2000s to date and further summarized as following in block diagram for easy understanding. These objectives are considered as single or multiple for Optimal Allocation of DG in the presence of equality and non-equality constraints. Fig 3, Summarized the review approach of the optimal allocation of DG in the form of a block diagram.

Optimal allocation and sizing of DG are not a linear method; rather they are solved as a non-linear optimization method. The optimal allocations of DG are mathematically modeled in the form of mixed-integer non-linear programming (MILP). The majority of the literature survey, carried out are basically methodologies to investigate the optimal allocation of renewable-based DGs in the distribution system for minimization power loss and cost associated. The authors in (Wong *et al.*, 2019), present a novel progress approach for optimal and sizing distributed generation with the placement of control storage in order to investigate the challenges of deploying Energy storage system in the distribution system. In Ref (Sedighi, 2010), authors applied Particle Swarm

Optimization (PSO), for optimal sitting and sizing of DG in the distribution system as well as boost the voltage profile and total harmonic distortion reduction. Also in (Rugthaicharoencheep and Sirisumrannukul, no date), an investigation was carried out by the authors to determine the importance of optimal reconfiguration of feeders within a given distribution system using a fuzzy logic approach, in order to minimize power loss, feeder balancing, and switches operation.

Ref (Soudi, 2013); studied the optimal planning of DG considering the significant and cost associate in order to improve power quality and greater reliability of the system. (Kaur, Kumbhar and Sharma, 2014); proposed a mixed-integer nonlinear programming technique for optimal placement of multiple DGs in a distribution network power loss minimization. Ref (Moradi, Tousi and Abedini, 2014), proposes a multi-objective optimization for sitting, sizing and placement of the DG in an optimal position to minimize power loss, voltage variation as well as stability. Ref (Angarita *et al.*, 2016); also presented a novel for optimal allocation of DG in distribution system the major objective is the minimization of electrical power loss and regulate voltage profile. Authors in (Subramanyam, Tulasi Ram and Subrahmanyam, 2018); presented an optimize dual-stage approach for setting and sizing fuel cell in DGs for effective system minimization. Ref (Hung, Mithulananthan and Bansal, 2010), proposes an analytical optimization to determine size and power factor correction in the active primary distribution network to reduce losses associated with deploying DGs in DN. Authors in Ref (Hassanzadehfard and Jalilian, 2018), proposes an optimization technique for proper sizing and locating renewable-based DG considering load growth in the active distribution system. The major finding is the placement of solar and wind in optimal place in DN to reduce operational cost, maintenance cost as well as Greenhouse gas emission. Authors in (Badran *et al.*, 2017), have focused on optimization techniques for network reconfiguration considering different methodologies to alleviate total power loss in the distribution system. Also authors in (Abou El-Ela, Allam and Shatla, 2010), major findings were an investigation on using Genetic algorithms for maximal placement of DG in the network system in order to boost voltage profile, spinning reserve control as well as a reduction in total power line losses. (Karimi *et al.*, 2016), proposes a multi-objective stochastic approach for integrating DG in the distribution network by considering economical, technical and environmental aspects by considering uncertainty. Major findings by authors were how safe is it to integrate DGs in DN to determine optimal location and size by considering some environmental parameters. Authors in

(Taylor, no date), carried out a cost benefit analysis to determine the optimal position to place DG in DN. The investigation is in terms of placement of DG in an optimal position by considering the size of the DG and capacitor. In ref (Kumawat *et al.*, 2017), perform a swarm intelligence based optimization for the planning of DG in DN to minimize annually energy loss. Findings by the author were to observe the behavior of a nonlinear electrical load with time-varying characteristics to obtain the real load in the DN. Also in (Kanwar *et al.*, 2016; Tlbo *et al.*, 2017), carried out optimization techniques for optimal placement of DG in the distribution system considering network reconfiguration, shunt capacitor and DG in the radial distribution system.(Hassanzadehfard and Jalilian, 2016), proposes a novel met the heuristic mathematical objective for placement of multiple DGs in an optimal position within the distribution system to minimize the cost associated with deploying DG. (Singh, 2016), applied a particle swarm optimization algorithm to find the best location to place their DG within the given electrical distribution network, the aim is to minimize total power losses and enhanced voltage profile. Reliability indices topology were adopted by (Siddappaji and Thippeswamy, 2017), to determine the best placement of DG in a distribution system for total power loss reduction using a fast decoupled method. Authors in (Gupta, 2017), investigated the effect of placement of multiple DG and STATCOM in the radial distribution system. This will help in mitigating the effect of power quality, and harmonics introduce by non-linear loads in a radial system. Authors in (Soroudi and Amraee, 2013; Aien, Rashidinejad and Fotuhi-firuzabad, 2014; Zhao *et al.*, 2015; Aien, Hajebrahimi and Fellow, 2016; Grechuk and Zabarankin, 2018; Jordehi, 2018), carried out a review on a different aspect of uncertainty modeling of DGs. The applied method can be summarized in Fig 2.3**.**

2.3.1 Various DG planning models

Uncertainties and fluctuation are the primary difficulties related to Renewable energy technologies, particularly with non-consistent accessibility of wind, sun based and hydro sources. To suit the incorporation of an enormous offer of variable energy sources, it is critical to have fitting arranging devices ready to enhance the reconciliation of variable renewable energy sources. Numerous advancement systems identified with vitality issues when all is said exist in the literature, for example, intelligent search techniques. In central, searching for the ideal site and limit the search of Distributed Generation is typically modeled as a non-linear optimization hurdle.

Different limitations and objective constraints are first set. The advancement strategy helps in decision making by creating an optimal solution from a decreased in initial set up of variables. Comprehensively, there are two ways to deal with the issues, by precise strategies, for example, Mixed-Integer Linear Programming (MILP) which is generally exceptionally modeling, however, require inordinate processing time and difficult to actualize on genuine size issues, and heuristic techniques which depends on improving the issue and offering fulfilling arrangements. In this area, a straightforward definition of the most widely recognized issue is introduced, which is to locate the ideal DG size and location for the bus that minimizes the total power loss (Abdmouleh, Gastli, Ben-brahim, *et al.*, 2017). It is important to assign distributed generation units at optimal places with appropriate sizes to reduce negative impact in terms of economic, technical and environmental factors. Several advantages of placing DG in an optimum position include; Enhancing voltage profile, stability and reliability increased, minimization of total power loss and power quality issues. In this section, various approaches will be discussed in detail.

DG's are classified into four major distinct group based on their terminal performance in terms of real and reactive power delivering capability as follows:

1) Type 1: DG capable of injecting P only.

2) Type 2: DG capable of injecting Q only.

3) Type 3: DG capable of injecting both P and Q.

4) Type 4: DG capable of injecting P but consuming Q.

Photovoltaic, micro turbines, fuel cells, which are integrated to the main grid with the help of converters/inverters are good examples of Type 1. Type 2 could be synchronous compensators such as gas turbines. DG units that are based on synchronous machine (cogeneration, gas turbine, etc.) fall in Type 3. Type 4 is mainly induction generators that are used in wind farms.

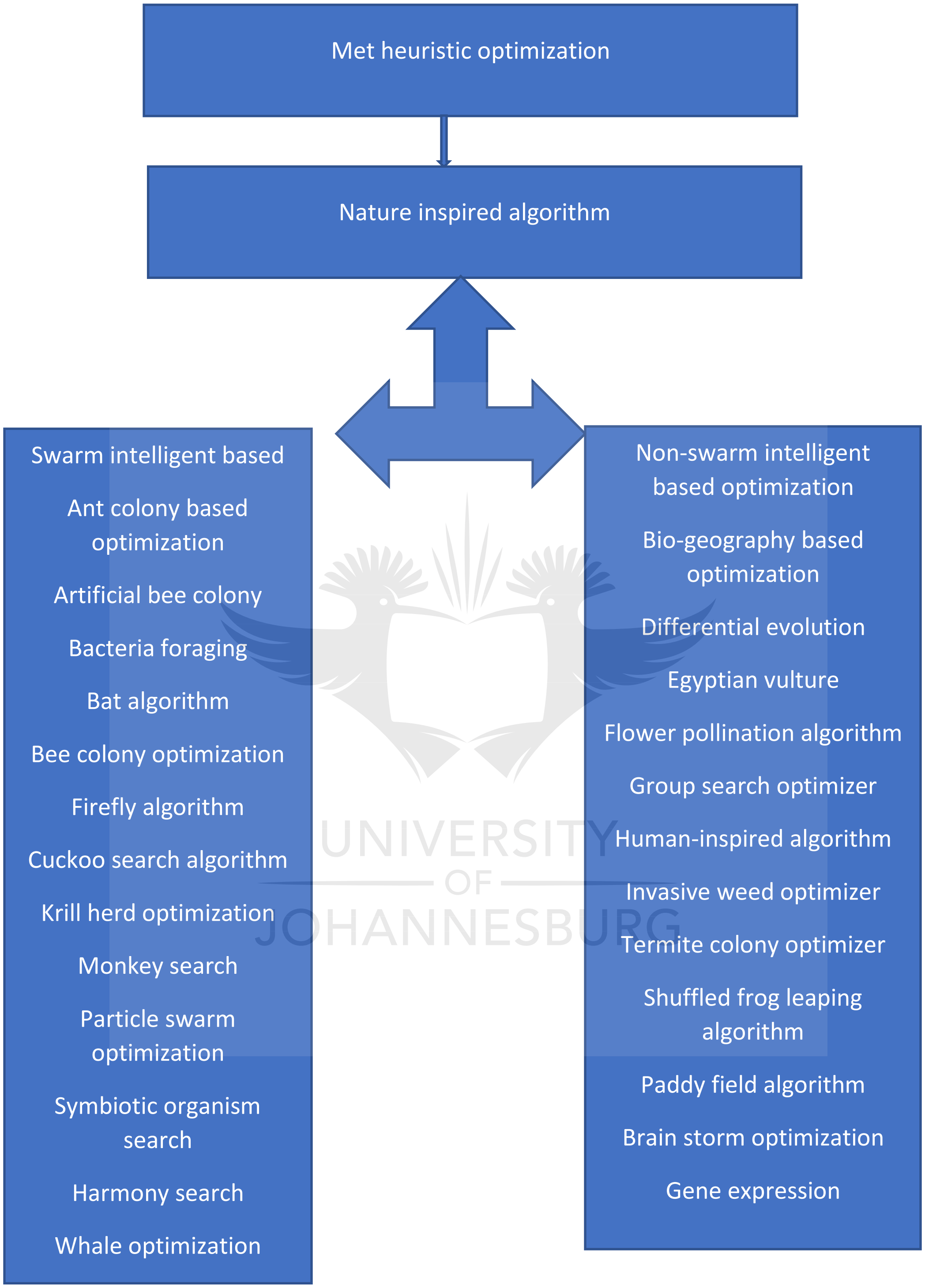


Fig 2-3: Shows various met heuristic optimization algorithms [195]

2.3.2 Analytical approach

Analytical approaches usually used for numerical approximation. The analytical algorithm approach for determining optimal DG size, location and installation has been reported in the literature by different authors (Hedayati, Nabaviniaki and Akbarimajd, 2006; Gözel and Hocaoglu, 2009; Hung, Mithulananthan and Bansal, 2010; Aman *et al.*, 2012). Authors in (Yarahmadi and Shakarami, 2018), proposes an analytical solution for optimal allocation of wind-based in radial distribution by partial derivative taking into account distinct time and voltage-dependent load using a multi-objective index for efficient placement of the DG wind in an optimum location. The objective goals were based on the use of the Rayleigh pdf model to determine the nature of the wind penetration, the result obtained was tested on 33 and 69 bus system. In ref (Wang and Nehrir, 2004), the authors propose an iterative method based on analytical to determine the best location to place a DG in a radial distribution network. The objective was to minimize power loss in the network system. Placement of the DG was analyzed in a radial feeder system, the location of the bus site was obtained from the different combination of the load's sources and finally, an analytical system was applied to generate the bus admittance matrix in the distribution system and tested on IEEE 6 and 30 bus system. Ref (Acharya, Mahat and Mithulananthan, 2006), used exact loss formula based analytical expression for placement of the DG in an optimum location to minimize total power loss in the primary distribution system. The basic objective was to calculate optimum size and methodology to place the DG in the best location to minimize system losses. A mathematical objective was formulated in (Viral and Khatod, 2015), to determine the optimal setting and sizing of the DG based on the analytical approach in the radial distribution network to minimize power loss on the system. The novelty of the work is the application of a simple analytical formula to minimize power system losses, with the presence of active and reactive components and the result obtained were tested on 15 bus systems and found to fit the objective as proposed.

2.3.3 2/3 rule

The 2/3 rule also known as the golden rule, it is a well-known analytical technique used for optimal allocation of DG. Optimally used for placement of shunt capacitors in a radial distribution system based on power flow. Here the size of the capacitor placement based on the DG is 2/3 of the incoming capacity generated is size to fit 2/3 length of the line in the system. This rule is applicable where the load is uniformly distributed in a radial network see (Rau and Wan, 1994; Willis, 2002) for details on the golden rule.

2.3.4 Sensitivity analysis-based Approach

These techniques are basically used to find the exact location of the distributed generation based on sensitivity index node identification, and tend to find the feasible location for our DG in order to minimize total power loss (Murty and Kumar, 2015), also applied in (Rau and Wan, 1994). However various literature has reported on the use of analytical analysis based on the sensitivity factor due to its simplicity (Gozel *et al.*, 2005; Acharya, Mahat and Mithulananthan, 2006; Kashem *et al.*, 2006; Hung, Mithulananthan and Bansal, 2010; Murty and Kumar, 2015). Authors in (Khatod, Pant and Sharma, 2013), propose a sensitivity analysis technique based on active and reactive power, to give the best location for placement of the DG thereby reducing the computational time.

2.3.5 Linear and non-linear Programming (MINLP)

The first set of iteration to solve non-linear programming is setting the direction of the search a linear programming problem is characterized by linear functions of unknowns, the objective of linear programming is that the unknown is linear and the constraints are linear inequalities. However, the popularity of linear programming depends on the primary formulation of the analysis. The concept of non-linear programming has been reported by different authors in literature (Cerone, Fosson and Regruto, no date; Luenberger, 1973; Felix F. Wu *et al.*, 2005; Kumar and Gao, 2010; Rueda-medina *et al.*, 2013; Ballesteros-Pérez, Elamrousy and González-Cruz, 2019; Jaravel, Wu and Ihme, 2019). However, the mathematical concept of solving advanced models is mixed-integer non-linear programming (MILNP). Mixed integer non-linear programming refers to optimization problems with continuous and discrete variables, the constraints imposed are in the form of a non-linear function. MINLP has a wide range of application including finance, engineering, and manufacturing process. MINLP has been used by the various author to determine the optimal size and location of DG in an electric power distribution system as discussed by (Paaso, Liao and Cramer, 2014; Popović, Kerleta and Popović, 2014; Nemati, Braun and Tenbohlen, 2018; Home-Ortiz *et al.*, 2019). They can be used to solve load models having the time-varying function by converting loads in the form of discrete probabilistic to deterministic generating load model as reported by (El-saadany, 2010). Despite the benefits of MINLP in solving the DG allocation and sizing problem, there exist some drawback of having a large number of decision variables and longtime computation.

2.3.6 Dynamic Programming

Dynamic programming was first introduced in the 1940s by Richard bellman aiming in solving the problem in which the optimum decision variable is sequential in nature. The dynamic word represents a time-varying function problem applied in mathematical optimization to solve problems in the form of optimal decisions. In (N. Khalesi, Rezaei and Haghifam, 2011a), proposes a multi-objective function based dynamic programming to determine a feasible location to place our DG within the distribution network to minimize power loss and improvement in the reliability of the system. Also, the author in (X. P. Chen *et al.*, 2017), develop an optimization strategy based on dynamic programming to address energy management problems, as they suffer recently due to the expansion of a number of variables. The objective was to design a new optimization strategy for energy management in combined heat and power (CHP) with hybrid energy storage and delivered based on the Dynamic programming approach. The DG allocation problem can be formulated as follows:

$$f_n(Kn, Ln) = Zn(Ln) + Max\sum_{L=n+1}^{Nloc} ML(X_L) \quad (2.1)$$

Subjected to:

$$\sum_{L=n+1}^{NLoc} X_L = Kn \quad (2.2)$$

Here; N_{Loc}: Number of potential nodes

2.3.7 Meta-heuristic approach

A meta-heuristic approach is an iterative approach that guides a subornative heuristic, combine artificially intelligent and mathematical optimization for solving a complex problem vastly than the classical method, generally used to find an approximate solution where the classical have failed. However meta-heuristic approach can be summarized in figure 4. Several meta-heuristic approaches for optimal allocation and planning of DG have been studied by various authors in the distribution network system. Such as, artificial bee colony (Kefayat, Ara and Niaki, 2015; Mohandas, Balamurugan and Lakshminarasimman, 2015; Das *et al.*, 2018), Cuckoo search algorithm (Nguyen and Truong, 2015; Sudabattula and M Kowsalya, 2016; Devabalaji, Yuvaraj and Ravi, 2018; Yuvaraj and Ravi, 2018), Symbiotic organism search (Das, Mukherjee and Das, 2016), harmony search (Maleki and Pourfayaz, 2015; Kayalvizhi and Vinod, 2018; Rastgou, Moshtagh and Bahramara, 2018), Bacteria foraging (Devi and Geethanjali, 2014; Devabalaji and Ravi, 2016; Kaveh, Hooshmand and Madani, 2018) , Bat algorithm (Sudabattula and M, 2016; Yammani, Maheswarapu and Matam, 2016), Whale optimization (Prakash and Lakshminarayana, 2018), Stud Krill herd (ChithraDevi, Lakshminarasimman and Balamurugan, 2017), Grey wolf optimizer (Yahiaoui *et al.*, 2017; Lakum and Mahajan, 2019), Firefly algorithm (Fister, Yang and Brest, 2013; Othman *et al.*, 2016). Equation (2), is applied for solving classical optimization and is applied to the position of vectors of PSO.

$$X_{id} = X_{id} + sign[2(k - 0.5)]\gamma v\max_{d} \tag{2.3}$$

were X_{id} is the dimension of the vector particle

$v\max_{d}$ is the dth dimension of the maximum vector

K is the random variable selection in [0,1] and γ is a constant value in the range of [0,1].

2.3.8 Simulated Annealing

Simulated annealing process begins in 1983 by Galett, vecchi and since its inception to date; it has reported being used widely due to its simplicity. It is in the form of probability function which allows new solutions to pass or reject, in order to avoid been trapped in a non-optimum position. Various literature has captured the use of simulated annealing for details ('A solution to the optimal power ¯ ow using simulated annealing', 2003; Friesz *et al.*, 2008; Popović, Kerleta and Popović, 2014)Authors (Kamal EL-Sayed, 2017) have applied simulated annealing optimization for minimization of power losses and enhancing the voltage profile. In ref (Sutthibun and Bhasaputra, no date), a multi-objective optimal placement of DG based on simulated Annealing was performed in order to reduce power system losses, control emission and contingency. The model was tested on IEEE 30 bus and there was a total power reduction up to 43% compared with the system without

DG. Multi-objective optimal planning of DG using simulated annealing was proposed in (Dharageshwari and Nayanatara, 2015), to reduce total power loss and improvement in voltage profile. Suitable fast convergence was attained by the placement of multiple DG and tested on the IEEE 33 bus and efficiency of the system improved, reduction in system losses and cost reduction.

2.3.9 Tabu search (TS)

Tabu search is a global Meta-heuristic optimization for controlling embedded systems. The search was proposed in 1986 by Glover and McMillian, based on human memory efficiency to solve the optimization problem. The basic principle of this search is on adaptive memory exportation that allows an anomic way of searching a solution until a better result is obtained (McMillan and Glover, 1986; Hilal, 2017). A genetic-based on tabu search was proposed by (Sutthibun and Bhasaputra, no date), for optimal placement and allocation of DG in the distribution network. The objective of the algorithm is to minimize power frequency losses and harmonic power losses in a distribution network system, and the proposed methodology was applied to the IEEE-14 and 34-node test systems. Thus, the proposed methodology is efficient for solving the DG allocation problem in the distribution system.

2.3.1.1 Shuffled frog leaping (SFLA)

SFLA is used based on the behavior of the frogs in rotation to search for food (Eusuff, Lansey and Pasha, 2006). In (Afzalan, A. Taghikhani and Sedighizadeh, 2012), optimal placement of the DG in radial distribution was achieved by SFLA and the result obtained were tested on 33 radial bus systems. In ref (Moazzami, 2017), a proposed methodology based on an improved shuffled frog leaping algorithm (MSFLA) to achieve optimal placement and size of DG and distributed statistic synchronized compensator (D-STATCOM). The result was tested on the IEEE-33 bus and compared with the ones derived from the genetic algorithm and shows to be more effective than the existing one.

2.3.1.2 Artificial bee colony (ABC)

Artificial bee colony (ABC) algorithm is an optimization technique that simulates the foraging behavior of honey bees, and have been applied successfully too many problems. ABC is classified under swarm intelligence algorithms and develop in 2005 by karaboga. Ref (Das *et al.*, 2018), proposed an algorithm based on ABC for optimal placement of distributed energy storage system in the distribution system to minimize power losses, line loading, mitigation of network demand and general improvement of the voltage profile. The result obtained using the ABC algorithm was compared with particle swarm optimization (PSO) and found to perform better and faster convergence. ABC algorithm was proposed in (Abu-mouti and Member, 2011), for optimal sizing of DG, power factor and location to minimize total real power loss in the distribution system and was compared with the PSO approach and found ABC offered a better quality solution with the fastest convergence.

2.3.1.3 Other Promising Heuristic Optimization Algorithms

However other authors proposed a heuristic algorithm which is a powerful tool for optimal allocation, sizing, and placement of distributed generation problems in the distribution system.

- *Biogeography Based Optimization (BBO)* is an evolutionary algorithm that optimizes a function by stochastically iterative function. It describes a number of behaviors linked to that of fish, birds, and insects. BBO was introduced by Dan Simon launched BBO in 2008. An optimal location based on BBO for sizing of solar photovoltaic DG in the radial distribution system was proposed by (Duong *et al.*, 2019), by minimizing power loss and maintain a normal voltage, while controlling the effect of harmonics distortion not to exceed the limit. Results obtained were compared with genetic algorithm and particle swarm optimization and artificial bee colony it shows that the new algorithm is faster and less time to converge.
- *Bacterial Foraging Optimization Algorithm (BFOA*) The algorithm is stimulated by foraging properties of E. coli bacteria. Permitting to this, bacteria search the food in such a manner to maximize the obtained energy per unit time. The isolated bacterium also conveys to others by transporting a signal. In this process bacterium take decision for searching food after examine two preceding factors in this, the bacterium moves by taking small steps at the time of searching the nutrients known as chemotaxis (Prabha and Jayabarathi, 2015).
- *Invasive Weed Optimization Algorithm (IWO)* This algorithm was first presented by Mehrabian and Lucas in 2006. It is based on mathematical stochastic optimization algorithm. The technique is inspired by sensation of inhabitancy of invasive weeds in nature is based on weed biology and ecology Invading of weeds of cropping system is done by means of dispersal. Every invading weed

takes the unused resources in the field and matures to the flowering weed and yields new weed autonomously (Prabha and Jayabarathi, 2015).

- *Imperialist Competitive Algorithm (ICA)* This is one of the latest meta-heuristic algorithms suggested to address socio-politically inspired mathematically optimization issues. Ref (Eisapour-moarref, 2017), ICA was proposed for multi-objective location and sizing DSTATCOM in the distribution system considering uncertainty in loads. The proposed algorithm tested on IEEE 33 and 69 bus system and there was total loss reduction, voltage profile improvement, feeder load balancing and cost reduction in the distribution system.
- Lightning Search Algorithm (LSA) is a new effective meta-heuristic optimization method for solving real numerical optimization concepts. LSA is inspired by the natural phenomenon of lightning and based on the mechanism of step ladder propagation. Ref (Thangaraj and Kuppan, 2017), proposed a multi-objective simultaneous placement of DG and DSTATCOM based on LSA for minimizing total power loss and voltage deviation, tested on IEEE 33 and 69 bus system and there was a significant improvement when the new algorithm was tested.
- Firefly Algorithm (FA) is a met -heuristic algorithm that is inspired based on the flashing behavior of fireflies. The firefly's flash acts as a signal system to seduce other fireflies (Nadhir, 2013). In (Taylor *et al.*, no date), optimal planning of distributed generation in the distribution system was achieved through the FA algorithm with the objective of minimizing power loss and voltage control.
- Dragonfly Algorithm (DA) is a new met- heuristic optimization, which is based on simulating the swarming behavior of dragonfly and was developed by mirjalili in 2016. In (Suresh and Belwin, 2018), DA was used for optimal placement of DG unit size at different power factor in order to reduce power loss in the distribution system and enhancement of the voltage profile of the system.

2.4 Overall review of studies on optimization of the distribution system

Considering and reviewing the study work on the issue of optimizing the distribution system, the following threads are described as deficiencies and directions for future works. Additionally, **table 6** includes merit and de-merit of different research work discussed.

- The majority of the research work carried out the optimization of distribution networks based on renewable energy sources did not consider uncertainty only a few. However, taken these uncertainties into consideration gives the distribution network system a strong realistic solution that paves a way to a practical distribution network.

- Meta-heuristic optimization algorithms control parameters are not well fit and this has a significant impact on their computing efficiency. For the optimization problem on hand, there is a need to revise in literature in order to have a strong parameter for the meta-heuristic problem.
- In distribution system nowadays used plug-in vehicles as a new concept in the distribution network configuration. They are large loads that can have a drastic effect on the effectiveness of the distribution system. However, some studies were conducted to assess their impact on the problems of optimizing the distribution system. There is still a gap for a full assessment of the effects of the plug-in car scheme used in the distribution network system.
- Many literature studies focused on Lagrangian relaxation (LR), but the solution obtained in each iteration is not really feasible. Therefore, there is a need for more research on the LR parameters because the performance of the distributed algorithm depends on the parameters to achieve faster convergence.
- The impacts of communication inertia on the convergence performance of the algorithm have not been fully explored in literature studies. The problem of optimal resistance existing in communication infrastructure for designing strong communication needs to be responded to in order to have wide adoption in distributed optimization in the future.
- Generally, distribution network system is large scale integration, most of the existing optimization techniques study focuses on small scale distribution. For fitness and validation purpose optimization techniques should be considered.
- Regardless of the significant offered by distribution optimization planning most of the utilities present in advanced countries experience challenges in integration. Educating modern distribution system utilities with merits and de-merits will lead to a more practical system.
- However, newer heuristic techniques such as Bacterial Foraging Optimization Algorithm (BFOA), Shuffled Frog Leap Algorithm (SLFA), Invasive Weed Optimization Algorithm (IWO) and Simulated Annealing (SA) Algorithm may appear to be promising in future.

Table 2-5: Gives a brief Comparison of the merits and demerits of the main approaches study of distributed generation placement.

DG Placement method	Merits	Demerits	References
Analytical method	-it is a simple and easy technique with high computational time	-Handles only single objective of the distributed energy resource at a time and lack robustness	(Devi and Chaithanya, 2012)
2/3 rule /Golden rule	-simple to use for approximate techniques with uniform load	-not suitable for non-uniform load	(Willis, 2002)
Optimal power flow	Highly used for computational problems and time efficiency	Problems are formulated in a closed way and difficult to incorporate	(Pearmine *et al.*, no date; Dent, 2009; Dent *et al.*, 2010; Gabash and Li, 2012)
Mixed integer and non-linear programming	-Very exactness and high computational time reliability	Solutions are difficult to understand -constraints not clearly identifiable	(Parisio and Glielmo, 2011; Jabr, Singh and Pal, 2012; Mashayekh *et al.*, 2017; Kumar, Kumar and Sandhu, 2018;

			Home-Ortiz *et al.*, 2019)
Simulated Annealing	-statistical guarantee in finding an optimal solution -They often give a good solution -relatively easy for handling complex problems	-Relatively slow if the cost function is expensive to compute -The method sometimes can tell if it has to find an optimal solution	(Vallem, Mitra and Patra, 2006; Nahman and Perić, 2008; Aly, Hegazy and Alsharkawy, 2010)
Particle swarm optimization (PSO)	-Higher probability efficiency in obtaining the optimal solution -Less computational time -Few parameters adjustments -Convergence is faster here	-However, sometimes difficult to define initial parameters -Difficulty in convergence complex algorithm	(Guadix *et al.*, 2018; Nazari-heris *et al.*, 2018)
Tabu search (TS)	-capable of handling complex iteration problems -Applications are found in continuous and discrete variables	-High computational time due to many iterations.	(Nara *et al.*, 2002; Maciel and Padilha-Feltrin, 2009)

Ant colony search optimization (ACSO)	-capable of giving a rapid solution -convergence is guaranteed	-Difficulty in theoretical analysis. -Probability distribution changes due to iteration.	(Sheidaei, Shadkam and Zarei, 2008)
Artificial bee colony optimization (ABCO)	-simplicity, flexibility and robustness. -easy implementation. -easy to define the objective function.	-Effectively slow in sequential processing. -A higher number of objective function evaluations required for fitness.	(Dixit, Kundu and Jariwala, 2016; Gupta, Ratra and Tiwari, 2017)
Firefly search Algorithm	-codes are easy to understand.	-Slow convergence speed. -High probability of trapped in a local optimum.	(Othman *et al.*, 2016)
Cuckoo search	-Requires fewer parameters for setting up.	-slow in convergence and few solutions in literature.	(Nguyen, Truong and Phung, 2016; Sudabattula and M, 2016)

Table 2-6: Summary of these challenges are better explained in table

Technical	Commercial	Regulatory
Voltage effects	Cost of implementation	Rising appropriate regulatory policy
Power quality issues	Creating a market pool	
Protection and control	Establishment of incentive	
Stability effect		

Table 2-7: Potential emission reduction of Carbon (IV) oxide and electricity emission to be achieved in 2030 ([PNNL] Pratt, R.G., Balducci, P.J., Gerkensmeyer, C., Katipamula, S., Kintner-Meyer, M.C.W., Sanquist, T.F., Schneider, K.P., Secrest, 2010)

Mechanism	Reduction in electricity energy and CO2 emission. Direct (%)	Indirect (%)
Transmutation effect of consumer information and feedback systems.	3	-

Joint marketing of electrical energy efficiency and demand response application.	-	0
Categorization of analytics in the residential, small and medium building.	3	-
Quantification and ratification for energy Efficiency programs (M&V).	1	0.5
Shifting load to more efficient generation	<0.1	-
Conversion voltage reduction and advanced voltage control	2	-

Support perforation of renewable energy sources such as; wind and solar generation (25% renewable portfolio standard) RFS	<0.1	5
Support additional electric vehicles and plug-in hybrid vehicle system	3	-

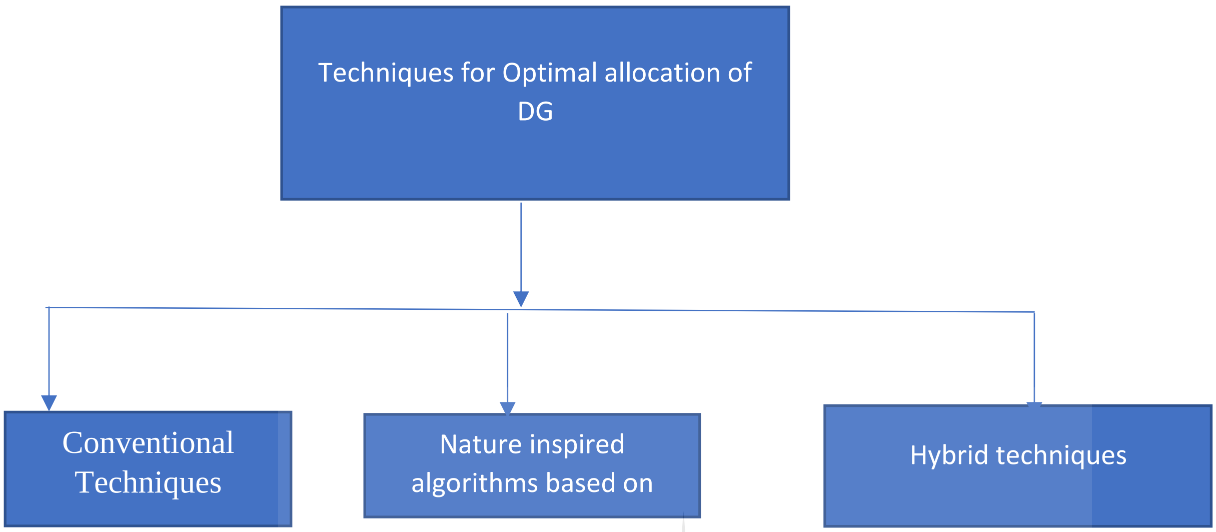


Fig. 2.3: Summarized techniques for optimal allocation of multiple DG

Table 2-8: Gives a summary of DG technologies and their ratings

Type of technologies	Size in (kW)	Electrical Efficiency (%)	Overall Efficiency (%)	Emissions (g/kwh)	Cost of Packing ($/kW)	Installation cost in ($/kW)	Cost to Generate electricity (kWh)	Cost of co-Generation	Reliability	Power quality
Non-Renewable technologies										
Reciprocating Engines/ spark Ignition	30-5,000	31-42	80-89	NOx: 0.7-42 CO: 0.8-27	300-700	150-600	7.6-13.0	6.1-10.7	✓	✓
Diesel	30-5,000	26-43	85-90	NOx : 6-22 CO: 1-8	200-700	150-600	7.1-14.2	5.6-10.8	✓	✓
Dual Fuel	100-5,000	37-42		NOx: 2-12 CO: 2-7					✓	✓

Micro turbines Propane, natural gas and Bio-gas	30-1000	20-30	60-75	NOx: 9-125ppm CO : 9-125ppm	900-1300	250-600	11.9-18.9	10.0-16.8	✓	✓
Industrial turbines	1000-5000	20-40`	70-95	NOx :25-200ppm CO :7-200ppm	200-850	150-250	8.7-15.8	5.8-12.2	✓	✓
Small Fuel cells	1-300	30-50	80-100	NOx: 0.007 CO: 0.01	4,000-5,000	400-1000	21.9-33.3	20.7-33.3	✓	✓
Phosphoric Acid	200	40	84	**NOx: 0.007 CO: 0.01**	3,000-4,000	360	18.6-22.8	17.0-21.2	✓	✓
Renewable energy technology									Reliability	Green power

Wind	5-1,000	-	-	-	1,000,3600	500-4,000	6.2-28.5	18.0-36.3	X	✓
Solar thermal	1000-80,000	30-40	50-75	-	-	-	-	-	X	✓
Photovoltaic	5-5,000	-	-	-	5000-10,000	150-300	18.0-36.3	-	X	✓
Geothermal	5000-100,000	10-32	35-50	-	-	-	-	-	x	✓
Biomass Gasification	100-20,000	11-25	60-75	**1500-3000**	-	-	-	-	x	✓

2.6 Conclusions and Future scope work

In this research work, the existing work carried out on optimization of the distribution network system has been reviewed from its point of view, in terms of the optimization algorithm, objectives, decision variables employ and models applied.

The sequence of this research has regarded over the past 10years an extensive evaluation of mathematical optimization in the power energy system and implementation of these techniques in planning and operating issues of DG's. Additional to the various trends, it has been noted that the area of Artificial intelligent is still the best technique evolving mathematical optimization of distributed energy sources (DER). However, the following conclusion is drawn from this article as follows:

- The area of artificial intelligence techniques is still receiving attention than conventional optimization techniques for optimal DG planning in a power distribution network system from a different point of view.

- Computational techniques in hybrid optimization techniques are faster and convergence faster than the conventional optimization techniques employed in optimal planning Distributed generation in a distribution network system.
- An analytical approach is not computationally difficult for a simple system but not suitable for a system with a large and complex network system.
- Meta-heuristic and hybrid optimization techniques are observed to be more suitable for a large and complex system as they provide optimum solutions to both single and multi-objective problems.
- It is further observed that for optimal distributed generation and sizing based on meta-heuristic optimization techniques such as; ABC, BBO, SFLA, ICA, and LSA are performing significantly well and may seem to be reassuring in future.

The following recommendation for future scope area of research is as follows based on the literature survey.

- The stochastic study should be adopted for optimal planning of the distribution network with the sporadic nature of distributed generation should be considered.
- Assessment of different types of DG and flexible ac transmissions (FACTS) controller planning in a static and realistic model by artificial intelligent (AI) techniques should be considered.
- A comparison of various different types of DG and FACTS planning via static and real-time models by the concept of hybrid AI should be considered in further research.
- Renewable energy sources based on DG units with battery storage option and their importance were not considered in this research.
- Operations of the DG in standalone mode should be considered in the future research scope.

CHAPTER 3

MULTI-OBJECTIVE FOR OPTIMAL PLACEMENT AND SIZING DG UNITS IN REDUCING LOSS OF POWER AND ENHANCING VOLTAGE PROFILE USING BPSO-SLFA

3.1 INTRODUCTION

The Institute of Electrical Electronics Engineering (IEEE) gives a concise definition of distributed generation as a power generation that is adequate compact than central generating plants and are connected closer to the distribution system (Chiradeja and Ramakumar, 2004; Pepermans *et al.*, 2005; Singh and Parida, 2015). The rapid development in technology, global concern about the environment and the demand of the customers for cheap and consistent electric power have led to an increasing interest in DG (Kansal, Kumar and Tyagi, 2016). However, optimal allocation and sizing of DG may bring various advantages such as voltage control through cost (El-Khattam *et al.*, 2004), boosting reliability (Rohatgi, Pregelj and Begovic, 2006), harmonic reduction (Tagore and Gupta, 2017), minimization of real and reactive losses (Mallipeddi, Suganthan and Amaratunga, 2017), voltage stability and network loss reduction (Esmaili, Firozjaee and Shayanfar, 2014), and infeasible network configuration (Nguyen, Truong and Phung, 2016).

Many optimization algorithm and techniques have been developed for the application of energy technologies problem. Among the various techniques, algorithms and optimization present the highest potential for use in the placement of DG. Nguyen et al. (Nguyen, Truong and Phung, 2016) adopted the novel cuckoo based (CSA) algorithm for placement of DG with the technical objective of minimizing the active power loss and improving the strength of the voltage. Yahiaoui et al. (Yahiaoui *et al.*, 2017) proposed GWO for the optimal sizing of hybrid renewable systems to lessen the cost of hybrid power generation. Other researchers have proposed a hybridization algorithm in order to replace the traditional algorithm. A particle artificial bee colony (PABC)-hybrid harmony search algorithm (HSA) approach was developed to optimal size and location of the DG in distribution system (Muthukumar and Jayalalitha, 2016). Their results showed that the efficiency of the proposed hybrid algorithm in obtaining optimal solution for simultaneous placement of DGs and shunt capacitors in distribution networks. Kefayat et al. (Kefayat, Ara and Niaki, 2015) applied artificial bee colony and hybrid ant colony optimization to the distribution system in order to control emissions expelled by the substation and overall improvement of the voltage stability. (Doagou-mojarrad *et al.*, 2013) reported a fuzzy based intelligent system based on shuffled frog leap algorithm to resolve optimal allocation problem with the aim of minimizing power loss, energy cost and control of emission produced. Results showed that the simulation illustrate the good performance and applicability of the proposed method. Another research conducted by (M H Moradi and Abedini, 2012), which obtained a better result in terms of reduction of loss of power, boosting voltage regulation, and maintaining voltage stability by application of particle swarm algorithm and genetic algorithm. (Selim, Kamel and Jurado, 2019), proposed chaotic sine cosine algorithm for optimal location and sizing DG in distribution network with minimum power loss and high convergence rate. Their results significantly shows how the new algorithm can be used to optimal allocate multiple DG units into radial distribution networks with technical objective of minimizing power loss, voltage deviation and maximize voltage stability index. (Menesy *et al.*, 2019), developed a Chaotic Harris Hawks optimization technique for estimating the exact operating parameters for proton exchange of fuel cell for high electrical performance. The author's findings are estimated data obtained by the proposed CHHO shown a good agreement with the experimental data of different commercial PEM fuel cell stacks.

As previously reported that the electric DG system for reduction of power loss and improvement of bus voltage stability, most widely used methods are reconfiguration and DG allocation (Sambaiah and Jayabarathi, 2019). Optimal network reconfiguration and DG allocation offer maximum essential benefits. Since combination between reconfiguration and DG allocation is an important and complex non-linear constrained optimization problem. The optimal configuration of feeder for minimizing forms of cost and maximizing reliability index can be obtained using hybrid PSO-SLA (Gitizadeh, Vahed and Aghaei, 2012). A hybrid particle swarm optimization (HPSO) was presented by (Alrashidi and Member, 2007), the research aimed to lessen the real power, fuel cost, and reduction of gaseous emission produced by the generating plant units. Similarly, Khalesi et al. (N Khalesi, Rezaei and Haghifam, 2011) examined the multi-objective function of locating DGs in radial distribution networks. Time varying load is employed in this optimization to attain the practical outcomes of the study and their needs are based on cost or benefit forms. They concluded that to eliminate the multi-objective problem, novel approach based on dynamic programming is required.

There are various researches published on optimal allocation and placement of DG, but very few have evaluated BPSO-SLFA, because it can be difficult to define the initial parameters. But BPSO-SLFA are proposed to decrease high dimensionality of the feature set and to select optimized feature subsets. A new methodology is proposed to minimize loss of power and boost the voltage profile using a combination of BPSO-SLFA. The BPSO-SLFA is a new proposed algorithm that works based on reconfiguring the DG in a momentary path, and is used to solve multi-objective function. This paper developed a BPSO-SLFA-based algorithm to optimal locate and size DG position with the suggestion of multi-objective function for reconfiguration and DG installation, loss of power system, and stability of voltage. The developed methodology is analyzed on IEEE 33 & 69-bus radial distribution systems. The obtained results show effectiveness and robustness of the proposed methodology in solving optimal location and sizing the DG in the DN and reduces total power loss and boost voltage profile within a defined network system.

Furthermore, the research aimed to explain the problem formulation methodology, the types of DG and fundamental background of the proposed hybrid and BPSO-SLFA algorithm, and optimization problem for the optimal DG method and simulation. However, the main contribution of this research paper is summarized as follows:

-The proposed algorithm is applied for resolving optimal distribution network reconfiguration and optimal DG unit with the technical objective of decreasing power loss and enhancing voltage profile;

- First, the algorithm is exercised for resolving optimal DG placement that assess optimal allocation for connecting DG and their significance for solving reconfiguration transient problem.

- The obtained outcomes clearly indicate that scenario 4 (Multi DG installation with network reconfiguration) is found to be more effective in reducing power losses.

-The simulated results obtained from the proposed BPSO-SLFA are compared with the results of other techniques to assess the performance and effectiveness of the new proposed techniques.

The rest of this paper is structured as follows. Section 2 explains the methodology and problem formulation of BPSO-SLFA. Section 3 illustrates the conventional BPSO and SLFA algorithms for DG placement to access optimal allocation for connecting DG and their significance for solving reconfiguration transient manner. Section 4 describes the results and flowchart algorithm on four (4) different case scenarios. Lastly, the main conclusion is given in section 5.

3.2METHODOLOGY

Minimizing the losses of power, bus voltage stability, and maximizing voltage stability are considered as the fitness functions for the placement of the optimal sizing of this current research work.

3.2.1 Minimization of power loss

Electrical energy is produced from a long distance away from the user and is distributed between the transmission lines to a variety of distribution system on which the electrical utility works. Commonly, the distribution network system takes power and sent it to the consumer of load in order to aid their demands. Nevertheless, not all the power will be delivered 100% efficient due to losses that occur at the distribution network line. The loss of power in the network distribution system is absolutely dependent on the precise position and size of the renewable DG system. The real loss of power in a distribution system with given operational conditions are computed using equation (1), and is referred to as exact loss.

$$\text{Minimize Ploss (F1)} = \sum_{i=1}^{nbr} Ii^2 Ri \qquad (3.1)$$

Here:

Ii and Ri are the current magnitude and resistance corresponding to the circuit branch I, number of branches is represented by br. The branch circuit current is divided into two components, active component (Iac) and reactive component (Irc).

$$\text{PLa (F2)} = \sum_{i=1}^{n} I^2 aciRi \qquad (3.2)$$

$$\text{PLr (F3)} = \sum_{i=1}^{n} I^2 rciRi \qquad (3.3)$$

However, optimal placement of DGs can compensate the active loss components in the branch.

$$PG = PD + Losses \quad (3.4)$$

The real generator power and the demand power are given as PG and PD respectively.

Voltage limits:

Equation (5), is useful for improving the voltage profile as one of the key objectives.

$$\text{F4} = \sum_{Ni=1}^{NN} (V_{Ni} - V_{rated}) \quad (3.5)$$

3.3 OPTIMAL SITTING AND SIZING PROBLEM FORMULATION

The radial distribution system reduces actual losses of power by optimal placement of DGs in order to boost voltage profile and decreases network operating costs that are subject to different operational constraints. Objective functions of the problem are formulated mathematically. This research work uses novel approach based on BPSO-SLFA for resolving the problems related to optimal sizing and sitting of DG in the distribution system.

3.3.1 Major Contribution of this research work

The algorithm is initially exercised to solve the placement of the optimal DG, which determines optimal position for connecting DG and its values for reconfiguring in a momentary path. The simulated outcomes are compared with the ones of other proposed techniques to assess the impact and performance of the proposed technique. The flow chart describing the proposed BPSO-SLFA is shown in Figure 1.

3.3.2 Proposed Hybrid Algorithm

3.3.2.1 Basic Particle Swarm Optimization (BPSO)

James Kennedy and Eberhart first hosted classical optimization called BPSO, practical swarm optimization in the year (1995). This Particle Swarm Optimization comprises of a collection (swarm) of people (particles) moving in the search space, fitness values are determined by their trajectory movement. The particle is represented by a location-indicating n-length vector and has a vector v for present position update. The velocity vector is calculated according to the following equation in (6). In PSO, the location and each particle velocity at k iteration in the space search is defined by $X^i{}_k$ and $V^i{}_k$. The iterated particle velocity I is described as $k + 1$ $P^i{}_{lbest}$ and attained from Equation. (3.6).

$$V^i{}_{k+1} = \omega . V^i{}_k + C1. R1\ (P^i{}_{lbest} - X^i{}_k) + C2. R2\ (P^i{}_{global} - X^i{}_k) \quad (3.6)$$

Here:

the random functions are R1 and R2, and where the training coefficients are C1 and C2. The following result can be defined by equation (3.7).

$$\omega = \omega_{max} - \{(\omega_{max} - \omega_{min}) - \mathrm{k}_{max})\} \times k \quad (3.7)$$

Where, k_{max} donates the possible number of iterations. At the end of each iteration, thse sum of the old position and the new velocity position obtains a new location for each particle

$$X^i{}_{k+1} = X^i{}_k + V^i{}_{k+1} \quad (3.8)$$

The PSO formula remained unaffected. A logistic conversion $S(V^i{}_k)$ is used to achieve this amendment that is written in Eq. (3.9) and (3.10).

$$S(V^i{}_{k+1}) = sig\ mod\ e\left(V^i{}_{k+1}\right) = \frac{1}{1+\exp(V^i{}_{k+1})} \quad (3.9)$$

If rand $\propto$ $S(V^i{}_{k+1})$ then: $X^i{}_{k+1} = 1$; (3.10)

Else: $X^i{}_{k+1} = 0$;

The function $S(V^{i}_{k})$ is a restrictive sigmoid for achieving a new change and rand is a quasi-quantity selected from a constant distribution in the space of [0, 1]. However, Eq. (3.11), (3.12) and (3.13) defined the particle's dimension limits.

$$1 \propto B_i \propto B_{max} \tag{3.11}$$

$$0 \propto P_i \propto P_{max} \tag{3.12}$$

$$T_i = \{1,2, \dots, T_f\} \tag{3.13}$$

3.3.3 The SLFO Algorithm

(Eusuff, Lansey and Pasha, 2017), Developed the SLFA algorithm, a memetic meta-heuristic for generating hybrid optimization. This algorithm is a metaheuristic technique of optimization that simulates the memetic growth of a group of frogs while trying to find the optimum location which has maximum amount of food available. Memetic algorithms are adapted based on population approaches to optimization problems in heuristic searches. The word memetic has its origin in "meme" (Dawkins, R. (1976). " The Selfish Gene.", Oxford University Press, no date). Meme is assumed as the cultural evolution unit. The concept evolves in a way that is similar to biological evolution, the SLFA contains a population-based solution identified as memeplexes which are divided into a subset. Inside each memeplex the individual frogs do hold idea of the other frogs and causes them to propagate the pattern. The SLFA algorithm progresses in the form of memetic evolution through the time loops (Eusuff and Lansey, 2004). In accomplishing this target some network parameters must be fulfilled. One can describe the problem statement as in equation (3.14)

$$\text{Objective Function=Min (TLP)} \tag{3.14}$$

Where, $TLP = \sum_{i=1}^{n} I_i^2 R_i$ is the absolute loss of real power for the radial distribution syst3`em. The voltage is subject to the constraint $|V_{i\,min}| \le |V_i| \le |V_{i\,max}|$. Here, Ii is the total flowing current over the ith branch that is the position and size features of the DG. Ri is the branch resistance, and the number of branches in the system is denoted as n. The lower and upper limits of the ith bus voltages are Vimin and Vimax.

The SFL estimate joins the advantages of BPSO calculations based on inherited and social behavior. For S-dimensional variables problems, a frog i is defined below in equ (3.15)

$$X_i = (X_i 1 , X_i 2 \dots \dots \dots \dots X_{in}) \tag{3.15}$$

Afterward, the frogs are sorted in relation to their fitness in a downward order. The entire population is broken into memeplexes, each with n frogs (p=m ×n). The best and worst-fit frogs are identified as x_g. Then, a method similar to BPSO is implemented in each step to boost only the worst-fit frog in every complete cycle. Consequently, the frog's location having the worst suitability is modified as follows:

The frog position deviations are defined as follows

$$(D_{i)} = rand() \times (x_b - x_w) \tag{3.16}$$

$$\text{New position } X_w = \text{current position } (X_w + D_i) \tag{3.17}$$

The inequality that satisfies the fitness of the position is defined below

$$D_{\max \geq} D_i \geq -D_{\max}$$

Where, $rand()$ is defined as a random number between 0 and 1 and $D_{\max}$ is the maximum permissible change in a frog's position. If this method developed improved the results, it takes the place of the worst frog, or else the calculations in (3.16) and (3.17) will be repeated but with respect to the best global frog (replaces). In this case, if no change is feasible, a new solution will be randomly generated to replace the frog. SFL algorithm to optimize the location and capacity of DG to minimize losses and boost voltage profile. The Stages are given in sequential order as follows: The flow chart describing the projected BPSO-SLFA is depicted in Figure 3.1.

(1). Initialize to the start;

(2). Generate, p solutions population for the frogs in a random step;

(3). For each discrete situation $i \in p$: compute the robustness (i);

(4). The solution of the population p is selected in downward order of robustness

(5). Split the solution p into m memeplexes;

(6). In every memeplex;

(7). The best and worst frogs' values be control;

(8). Regulate the outfit location of frogs by applying equation (3.16) & (3.17);

(9). Repeat on a number of iterations of the defined system;

(10). End;

(11). integrate the develop memeplexes;

(12). Sort the population into fitness in their downward order;

(13). Verify if the end result is = true;

(14). End;

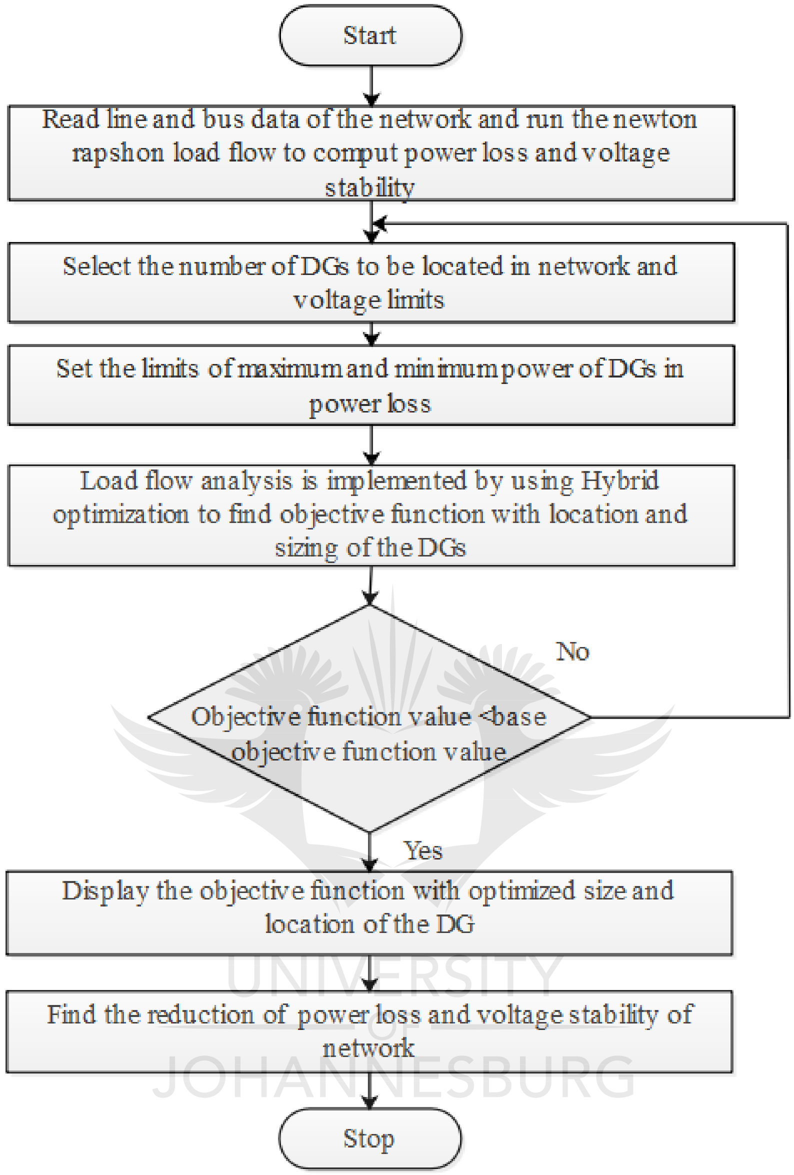


Figure 3.1: A proposed flowchart for the algorithm

Proposed Methodology of BPSO-SLFA

Figure.1 shows the flowchart for the location and size of the DG to be detected. The techniques for identifying the optimal size and position of DGs using the proposed hybrid optimization algorithm are outlined in the steps below.

Step 1: Data of the input line and data of the bus.

Step 2: Pick the number of DG units in the network for optimal placement.

Step 3: Fix the voltage limits with real and reactive limits of power for the DGs, the DGs power factor is set according to the reactive power compensation required.

Step 4: Run the load flow analysis to compute the total active loss of power and maintain voltage stability.

Step 5: Arrange the algorithm parameters which include frequency length, pulse rate, loudness and the number of iterations.

Step 6: Iteration is achieved through an efficient and hybrid optimization algorithm with objective function.

Step 7: The spot and size of DGs are randomly selected in each iteration while updating the frequency, velocity, and position.

Step 8: The main objective function is computed as in step 6.

Step 9: If the objective function attained is less than the current best solution, then the objective function attained is considered a new optimal solution, and the loudness and pulse emission rate are modified.

Step 10: Repeat step 6 and step 9, before evaluating the full iteration.

Step 11: Fix the best fitness function between all solutions and the corresponding location, until the optimal size of the DG is determined.

Step 12: Eventually, the base case is undergoing a comparative review. The network output is determined by the loss of power and stability of the voltage.

3.4 NUMERICAL SIMULATION AND RESULTS

In the previous work, the implementation of the hybrid BPSO-SLFA algorithm for optimal DG units, sizing shunt capacitor allocation problems in the distribution network was not explored. This inspires us to utilize a hybrid BPSO and SLFA algorithm approach to detect the location and size of DG units in order to reduce actual losses of power and maintain stability of voltage. The projected algorithm is realistic in resolving optimal reconfiguration of the distribution grid and optimum DG engagement with the goal of reducing power losses and boosting the voltage profile. Nevertheless, the algorithm is used to solve optimal DG placement which evaluates optimal allocation for connecting DG and is a momentary way of resolving reconfiguration performance achieved. The results obtained clearly indicates that in reducing power losses, scenario 4 (Multi DG implementation with reconfiguration of the network) in terms of reduction of losses of power are found to be more significant. The simulated results obtained are correlated with other literature reports, and are considered to be better in terms of reductions.

Scenario 1: The system with reconfiguration only

The reconfiguration process of the distribution system performed by using the optimization algorithm for handling the operation of switches. This optimization is used to overcome the concern over the selection of sectionalizing switches. The sectionalizing of switches has two states, one is open and another one is close. The open and closed states of the switches are defined by two different conditions such as 0 and 1.

Scenario 2: The system with DG units only

This scenario has a connection of multiple DG units (maximum 3 DG) in the bus system without any reconfiguration (base case scenario).

Scenario 3: System with single DG unit reconfiguration and installation

In scenario 3, there are two different steps processed. Firstly, the reconfiguration is performed in the desired bus system and then only one DG unit is connected in the reconfigured bus system.

Scenario 4: System with Multi DG unit reconfiguration and installation

The reconfiguration is performed in the bus system. Multiple DG units (maximum 3 DG) are connected with the reconfigured with standard 33 &69 IEEE bus system.

The planned methodology (BPSO-SLFA), is applied and tested on two standard distribution network, 33 and 69 IEEE-bus systems with base voltage as 12.66kV.

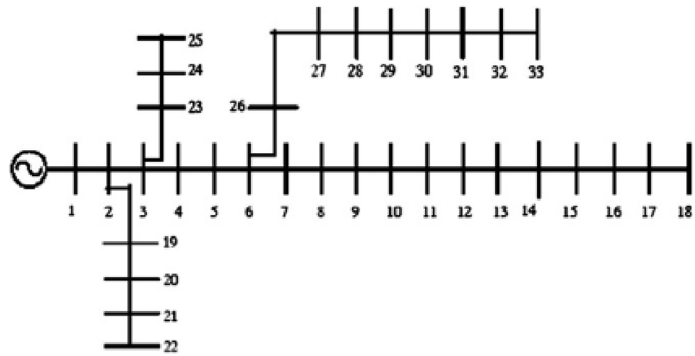


Figure 3.4: IEEE standard 33 bus radial distribution system Single line diagram (Baran and Wu, 1989).

Table 3.4: The performance of the planned BPSO-SLFA on the IEEE 33 bus system at different case study levels.

CASE 1	***Before DG Installation***	***After DG Installation***
Power loss:	202.68 kW	75.3241 kW
Reduction of loss of power:	________	62.8359 %
Minimized voltage:	0.91075 pu	0.92841 pu
CASE 2		
Calculated DG size= 1500.0000kW.		
Reduction of loss of power:		
27.9855		
CASE 3		
loss of power:	202.68 kW	46.6899 kW

Loss reduction in power:	________	76.9637 %
Minimized voltage:	0.91075 pu	0.91981 pu
CASE 4		
Power loss:	202.68 kW	31.2844 kW
Reduction of loss of power:	________	84.5646 %
Minimum voltage:	0.91075 pu	0.9547 pu

From Table 3.4, it is clearly observed that base case results losses for all four cases indicate scenario 4 with multiple DG deployment with reconfiguration option is found to be more effective in decreasing losses of power from 202.68 kW to 31.2844 kW. The internal parameters of the proposed algorithm modified for the MATLAB simulations are shown in Table 4.

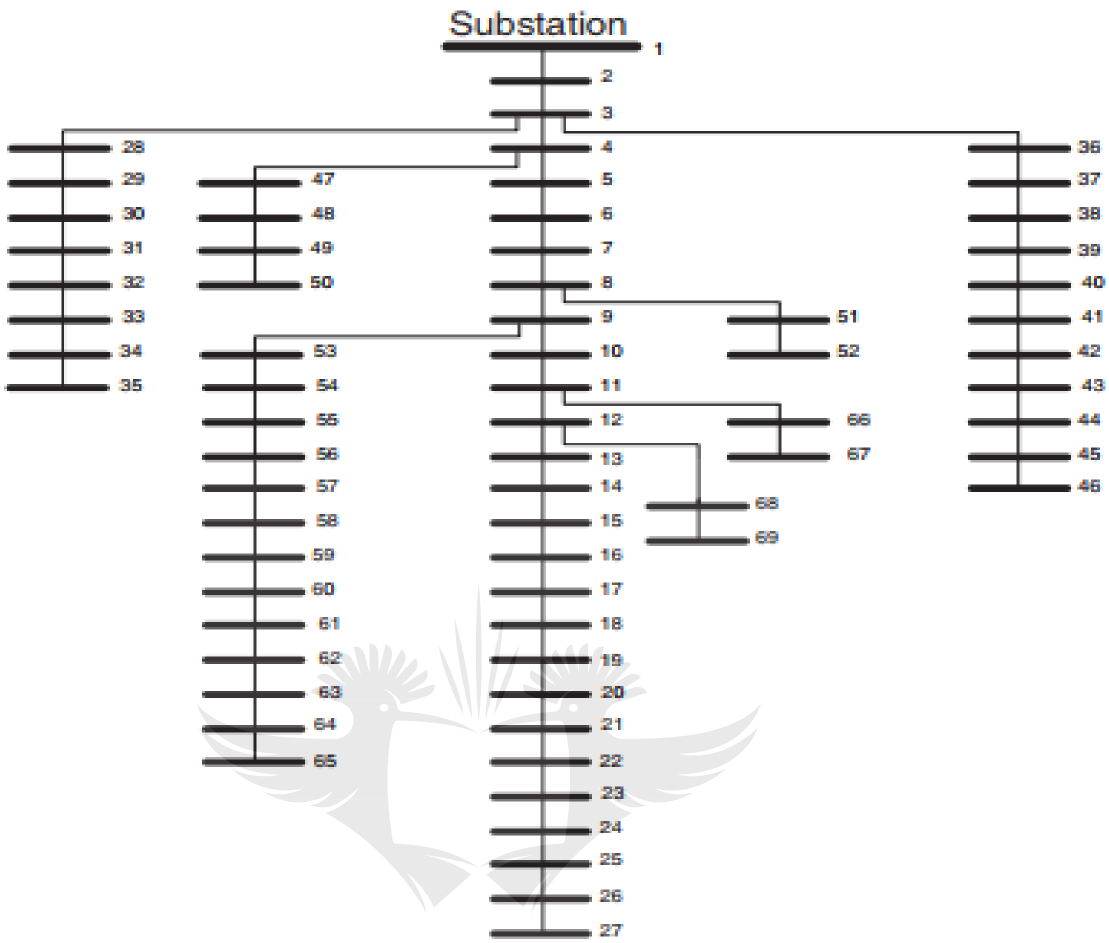
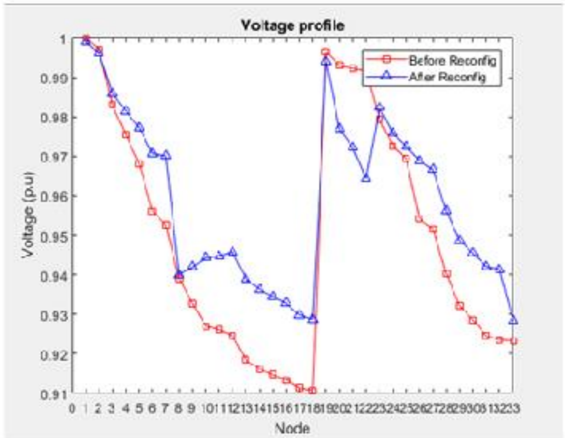


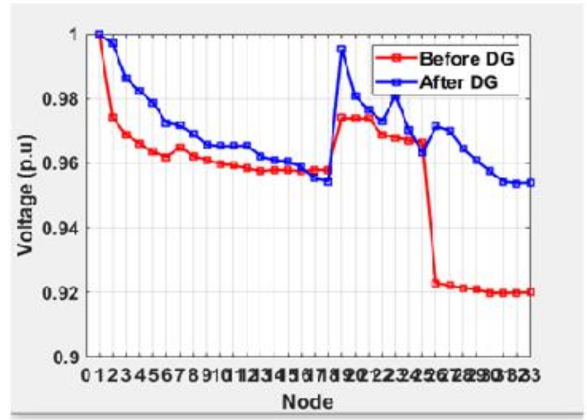
Figure 3.4: The IEEE 69 bus-radial network Single line diagram (Sahoo and Prasad, 2006)

3.4.1 Radial distribution systems of IEEE 33

The IEEE-33 bus system is a radial distribution system (RDS) with a total load of 3.72MW, 2.3MVar, 33 buses and 32 branches as shown in Figure 3.4. The line loading system and line data are obtained from (Baran and Wu, 1989). Table 3.4, describes the performance of the proposed BPSO-SLFA for all the four cases scenario. The line losses and voltage profiles of the IEEE 33 bus systems with network reconfiguration before and after DG for all the cases are shown in Figure 5. It is clearly observed from the results, that the voltages have better-quality with multiple installations of DGs and reconfiguration as shown from Figure 1C.



A



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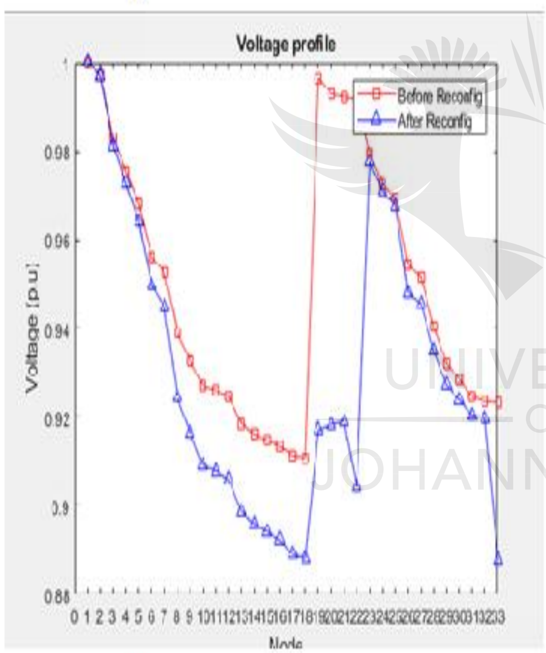
C



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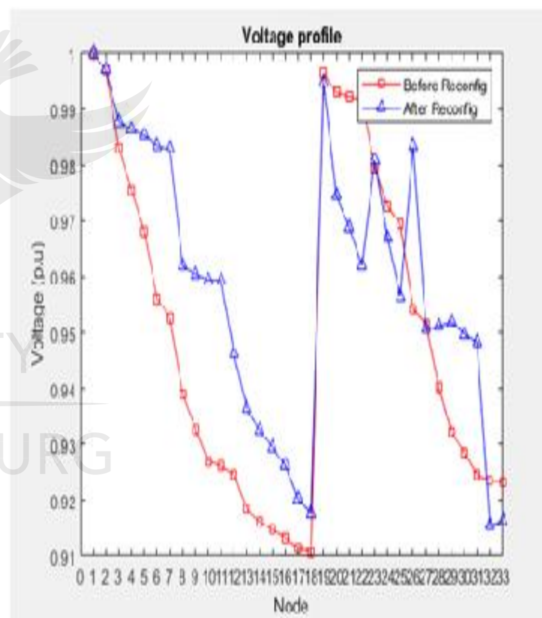


D

Figure 3.5(A-D): Voltage profile improvement before reconfiguration and after reconfiguration for all the four cases.

3.4.2 IEEE 69 radial distribution systems result

As shown in Figure 3.5, the IEEE-69 bus system is a radial distribution system (RDS) with a total real and reactive power load of 3.80MW, 2.69MVar, 69 buses and 68 branches. The system load line and line data are taken from (Sahoo and Prasad, 2006). The performance of the proposed BPSO-SLFA for all the four (4) cases scenarios are presented in Table 2. The line losses and Voltage profiles of the standard IEEE -69 bus systems with reconfiguration before and after DG for all the cases are shown in Figure 4. From Figure 4D it is observed that the voltage profile has improved with multiple installations of DGs with reconfiguration and comparison was given in Table 3, and shows the effectiveness of the new algorithms against existing ones. Figure 4 and 5 shows the voltage profiles and line losses of IEEE-33 and 69 bus systems with and without DG reconfiguration. From Figure 4 and 5, it is clearly observed that the minimized voltage profile has improved after installation of multiple DG reconfiguration network. This shows the effectiveness of the proposed algorithm. Table 2 illustrates the optimal network reconfiguration of all the cases under the study structure of the IEEE 69 bus system after the instantaneous reconfiguration of multiple DGs using the proposed technique. From Table 2, it is noticed that the Tie switches at 15, 40, 46, 19 and 18 are open at a suitable location and the size of the DG is given as 1.9246, 1.1350 and 1.7587 with precise optimal position of 13, 10 and 30 respectively. The quality, power loss reduction and improvement in voltage profile for the cases are observed in CASE 4, which demonstrate the preeminence of the proposed BPSO-SLFA.

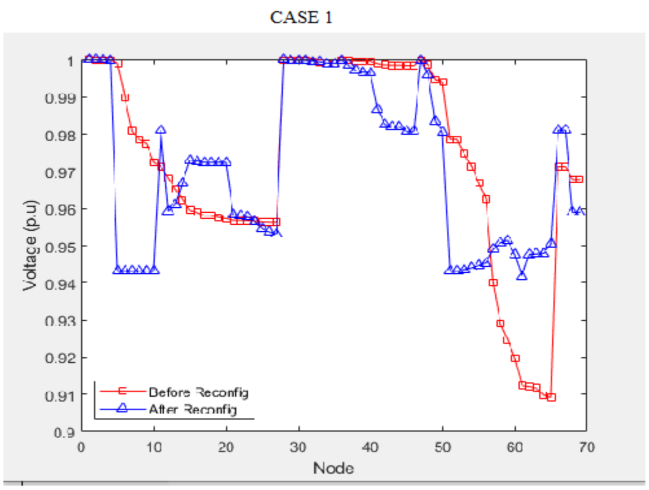
Table 3: Compares the results of the various methods for the test systems of the allocation of multiple DG units.

Case	Approach	Installed DG	Power loss (kW)	Loss reduction (%)
3 DG	Hybrid (Kansal, Kumar and Tyagi, 2016).	13, 0.79	81.050	61.62
3 DG	Hybrid* proposed	13, 10, 30	31.2844	84.5646
3 DG	Hybrid (HGWO)(Sanjay *et al.*, 2017).	30,24,13	2946	72.884
3 DG	Hybrid Big bang big crunch (Sedighizadeh, Esmaili and Esmaeili, 2014).	7,9,14,28,32	139.53	78.73

Note: Hybrid is the proposed new algorithm*

Table 4: Parameters of the proposed algorithm for the test systems under assessment

Test system
Balanced 33 &66 bus
N =20, dimension of search =5, Maximum weight (wmax) =0.9, Minimum weight (wmin) =0.4
Minimum average weight (wavg) kW= $0.31x10^{3}$, Maximum average weight (wavg) kW = $0.015x10^{3}$ population size (pop size) =10 bMVA =100, bkV =12.66 nbb = 33 & p.f =1



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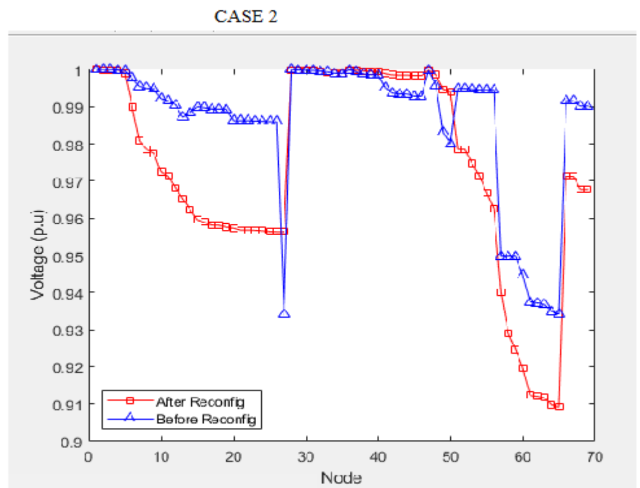

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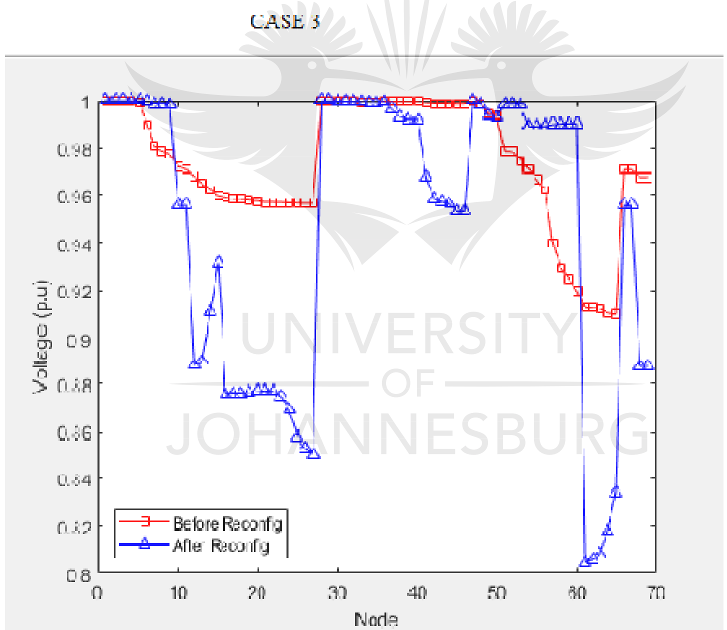


C

Fig 3.5(A-C): Voltage profile improvement before reconfiguration and after reconfiguration for all the cases.

Table 3.4.2: Performance of the proposed BPSO-SLFA on the IEEE 69 bus system at various level case study

CASE 1	*Before DG Installation*	*After DG Installation*
Reduction in power losses :	224.9804 kW	142.2289 kW
Power loss reduction:	________	36.7816 %
Minimal voltage profile :	0.90919 pu	0.94184 pu
	CASE 2	
	BEFORE DG	AFTER DG
Tie switches:	69 70 71 72 73	69 70 71 72 73
Power loss:	224.894 kW	152.1548 kW

Power loss reduction: _______	32.3438 %
DG size: 0.3296	
Optimal DG position: 8	
CASE 3	
BEFORE DG	AFTER DG
Tie switches: 69 70 71 72 73	62 9 63 44 7
Power loss: 224.894 kW	42.0942 kW
Power loss reduction: _______	81.2826 %
DG size: 1.8147	
Optimal DG position: 19	
CASE 4	
BEFORE DG	AFTER DG
Tie switches: 69 70 71 72 73	15 40 46 19 18
Power loss: 224.894 kW	67.841kW
Power loss reduction: _______	69.8342 %
DG size: 1.9246, 1.1350, 1.7587	
Optimal DG position: 13, 10, 30	

3.5 CONCLUSIONS

In this study, the authors have utilized BPSO-SLFA algorithm to assign DG of optimum size DG in power network distribution. It is clearly observed that the technical goal of hybrid DG installation and reconfiguration in scenario 4 was achieved. The proposed study was investigated on IEEE33 and 69-bus power network system by DG installation at the 13^{th}, 10th and 30^{th} bus and succeeding in terms of reduction in network power losses and improvement in voltage profile. The obtained result shows that BPSO-SLFA algorithm has the best result in power loss reduction, voltage profile improvement and enhancing reliability versus Hybrid GWO and Hybrid big bang big crunch for both test results. Hence, the proposed methodology can be used as a reliable method in DG setting and sizing in distribution network system bestowing to good enactment and the preeminent results rather than Hybrid GWO and Hybrid big bang big crunch.

1. More benefits of the recommended (PBSO-SLFA) algorithms have been achieved compared with other optimization algorithm, to solve optimal sizing and placement problem.
2. The power losses associated with the system, have significantly reduced up to 31.8244kW, using multi-DGs reconfiguration placement which is expected as part of the objective of the research work.
3. Significant improvement in voltage profile and Voltage stability boosted with reconfiguration and installation of multiple DG units has been achieved using controlled power factor.

CHAPTER 4

WATER, ENERGY &FOOD ALGORITHM WITH OPTIMAL ALLOCATION AND SIZING OF RENEWABLE DISTRIBUTED GENERATION FOR POWER LOSS MINIMIZATION IN DISTRIBUTION SYSTEMS (WEF)

4.1 INTRODUCTION

Distributed Generation has demonstrated an expanding measure of development in Power Distribution Network all over the world. This is because of the advancement in the usage of renewable energy resources and improvement in co-generation. This development has made DG more popular (Sulaiman *et al.*, 2012; Chatterjee, 2015). Distributed Generations are small scale power generation sources that are connected directly to the Distribution Network (DN) and close to the consumer load being served (Huda and Živanović, 2017). Hence, the size of the DN can be increased by integrating renewable-based technology. For instance, biomass generations and solar photovoltaic cell's needs (Huda and Živanović, 2017; Ehsan and Yang, 2018a), to provide dependable and cost-effective services directly to customers while ensuring power reduction losses, greenhouse gas emission, flexible voltage regulations, power quality, peak load shaving, and reliability enhancements (Li *et al.*, 2018).

However, bad allocations decrease the overall performance of the distribution system (Sudabattula and M. Kowsalya, 2016). Thus, it gained attention especially on developing methodologies for power losses minimization. For details, see (Georgilakis and Hatziargyriou, 2013; Rao *et al.*, 2013). (Wang and Nehrir, 2004; Acharya, Mahat and Mithulananthan, 2006; Gözel and Hocaoglu, 2009; Hung, Mithulananthan and Bansal, 2010).

Additionally, various algorithms have been developed to handle the issues related to DG in DN. For instance, Particle swarm optimization (El-Zonkoly, 2011a; M. H. Moradi and Abedini, 2012b; Jain, Singh and Srivastava, 2013), Artificial bee colony (Abu-Mouti and El-Hawary, 2011), Hybrid particle swarm optimization (Tolba, Tulsky and Diab, 2017), Harmony Search Algorithm (Parizad, Khazali and Kalantar, 2010), Dynamic programming (N. Khalesi, Rezaei and Haghifam, 2011b), Simulated Annealing (Kumar and Kumar, 2013), Mixed linear integer programming (Zhang *et al.*, 2012), Improved Analytical (Hung and Mithulananthan, 2013) and Analytical (Acharya, Mahat and Mithulananthan, 2006) are used to solve DG allocation issues for minimizing power losses. An analytical method based on the determination of power loss and minimization of real power losses allocation of both single and multiple DG in primary DN were presented in (Acharya, Mahat and Mithulananthan, 2006; Hung and Mithulananthan, 2013). However, this method does not provide actual computational time.

Harmony search optimization algorithm was proposed to optimally locate and size the DG in radial DN to minimize the total power losses (Yuvaraj, Devabalaji and Ravi, 2015). Simulated Annealing was used in, (Kumar and Kumar, 2013) while optimal sizing and locating a DG in large scale DN to minimize power loss sensitivity and optimal sitting is achieved by low sensitivity factor (LSF). (Murthy and Kumar, 2013). Hence, a comparison between loss sensitivity, index vector, and voltage sensitivity index was done to optimal locate and size the DG in DN.

However, the author only considers the case of the unity power factor without considering the optimal power factor. A particle swarm optimization was presented for both a single and multi-objective approach to determine a real position to place multiple DG in a DN to maximize power loss (Tan, Hassan, Rahman, *et al.*, 2013). Nevertheless, if a careful selection is made on the placement of the DG, it will become a real optimum solution. Thus, a simple search algorithm proposed in (Mahmoud and Oda, 2016), to investigate the possibility of connecting wind turbines in a radial distribution system, with technical objectives of boosting the stability of the system.

Subsequently, Algorithm requires large computational time to obtain results and only suitable for single-objective optimization problems. Ref (N. Khalesi, Rezaei and Haghifam, 2011a), proposes dynamic programming to find optimum DG location in the distribution system and to minimize total power loss and boost the reliability of the system for maximum profit. The clonal selection Algorithm was applied in (Hanumantha Rao and Sivanagaraju, 2012), to determine optimal DG's size and location in radial distribution system with the technical objective for maximization of energy savings.

Also in (Abdelsalam, Zidan and El-Saadany, 2015), optimization was proposed to address the issue of optimal sizing and sitting the DG in DN for voltage improvement, power losses, and Total harmonic distortions (THD). Ref (Muhtazaruddin and Fujita, 2013), proposed an artificial bee colony to provide a solution to output DG power and location to multiple DG sources. Big Bang crunch optimization algorithm was adopted in (Hegazy *et al.*, 2014), to find the optimal location and size of the DG to minimize power loss in a balanced and unbalanced distribution network system.

While, distribution planning was adopted by (El-Fergany, 2015), using a backtracking search algorithm to produce an optimum solution for DG installations to boost voltage profile and reduce power loss in the radial system. Hence, in this paper, a new Algorithm based on water, energy, and food was proposed and adopted from (S Sani *et al.*, 2019), to determine optimum size and placement of multiple DG's and to minimize power losses that arise in placement of our DG's in a non-optimal position in the distribution network.

Furthermore, a methodology was proposed for optimal multiple DG placement of Gas turbines (conventional) and renewable-based DGs such as (wind and solar) placement in DN operating at 0.8 power factor which is sufficient in reducing power losses and improvement of voltage profile within the specified constraints. The major objectives are to minimize total power loss and emissions produced by this conventional system. The modeling of this renewable energy system was carried out based on Weibull and beta distribution probability to determine to extract the power loss. In this research work, the best location for the placement of sources was determined using the Water, energy, and food algorithm adopted by (S Sani *et al.*, 2019).

4.2 Basic Water, Energy, and Food (WEF) Optimization Algorithm review

4.2.1 Water, Energy, and Food (WEF)

The concept of the WEF algorithm was proposed by (Sulaiman Sani *et al.*, 2019), it's a mathematical model developed to handle issues related to open-but-restricted-environment (OBR-E), which helps in achieving a sustainable environment. It's a strong model for predicting the state of an element combined at any time. In (Jin *et al.*, 2019), the authors proposed water, energy, and food Algorithm achieve a sustainable environment. In 2005, J. diamond surmises that it is essential for human beings to think about how to solve a complicated problem within the environmental using (WEF) (Jared Diamond, no date). Mohammad Al-Saidi and Nadir Ahmad affirm that this problem of achieving a sustainable environment includes water-energy-food linkage (Al-saidi and Elagib, 2017). Hence, we tend to apply this concept to achieve a greater sustainable distributed energy system.

4.2.2 Dragonfly Algorithm (DFA)

In 2015,(Mirjalili, 2016), Seyedali Mirjalii proposed a dragonfly algorithm. This algorithm was developed to monitor both the static and dynamic behavior of dragonflies. The search for foods marks the path of utilization and inform and guide others. These creatures find the optimal position and perform the task efficiently within their domain.

The static swarm creates a particular group and flies back over a small area and hunt for flying prey, while the dynamic swarm creates a massive number of dragonflies, which makes the swarm migrate in one positive over long distances.

These two phases can be mathematically expressed as follows:

$$let\ Ki\ be\ the\ search\ process\ of\ drangonflies\ during\ the\ search\ to\ avoid\ collision$$

1. $K_i = -\sum_{j=1}^{N} X - Xj$ (4.1)

X denotes the current position of the dragonflies, while Xj is the jth neighboring individuals.

N is the number of neighboring individuals

2. The alignment fitness is computed as follows:

Considering the movement velocity as Vi, in the matching process as searching is taking place.

$$Vi = \frac{\sum_{j=1}^{N} Xj - X}{N} \qquad (4.2)$$

J^{th} is the velocity of neighboring.

3. The cohesion is computed to attract the swarm towards the middle point of the grouping swarm.

$$Ci = \frac{\sum_{j=1}^{N} Xj - X}{N} \qquad (4.3)$$

X is the current position of individual

N is the number of Neighborhood

X_j Denotes the position at neighboring individual

4. The food attraction $(f*)$ by the swarm is mathematically computed to, attract the swarm.

$$f* = X^{+} - X \tag{4.4}$$

X is the current position of the individual

X^{+} is the food attraction source

5. During Food attraction, the enemy is always present and must put into consideration

$$E^{*} = X^{-} + X \tag{4.5}$$

X^{-} is the enemy position, while X in the initial position.

Lastly, the behavior of dragonflies during the searching period is modeled by the five governing equations given above in Equ (4.1)-Equ (4.5). However, in the process of searching the position and movements of these flies are amended by using a two-step vector.

$$\Delta X_{t+1} = (kKi + vVi + cCi + ff^{*} + eE^{*}) + w\Delta Xt \tag{4.6}$$

After calculating the step vector in equ (6), the position of the vector can be updated below.

$$X_{t+1} = X_{t} + \Delta X_{t+1} \tag{4.7}$$

Where t, Ki, Vi, Ci, fi, and Ei are the initial iteration, alignment, cohesion, food attraction, and enemy and distraction towards enemy outwards of i^{th} individuals. Also (k, v, c, f, and e) are the weighting factors for the different parameters. To assure the guarantee of convergence of the dragonflies during optimization, there is always a change in their adaptive weights. Equation (4.7) can be updated to obtain the position of the dragonflies as given below.

$$X_{t+1} = X_{t} + 0.01 \times \frac{r1 \times \sigma}{(r_{2})^{1/\beta}} \times X_{t} \tag{4.8}$$

$$\sigma = \left(\frac{\Gamma(1+\beta)}{\frac{(1+\beta)}{2}} \right) \times \left(\frac{\sin \frac{\beta\pi}{2}}{\beta \times 2 \times \frac{\beta-1}{2}} \right)^{\frac{1}{\beta}} \tag{4.9}$$

4.2.3 Active power loss minimization

Electrical power energy is generated from a long-distance far away from the consumer side and is transported through the transmission line to many distribution circuits systems that the electrical utility operates on. Generally, the distribution network system will take power and sent it to the consumer of the load to serve their demands. However not all the power will be delivered 100 percent efficiently due to losses that occur at the distribution network line. The power loss in the distribution network system is dependent on the precise location and size of the Renewable DG system. The real power here is obtained and defined by (El-Zonkoly, 2011b; Oda *et al.*, 2017).

$$E_4 PLoss = \sum_j^{bn} (Ij)^2 Rj \tag{4.10}$$

Where Ij and Rj are the current magnitude and resistance corresponding to the J^{th} branch, bn is the number of branches.

It is observed from equation (4.10), that the total power loss will be affected when the line current changes. However, minimizing the total real power loss can be achieved by optimal placement and sizing. The renewable-based DG in the distribution system is defined by the equation, (4.11) below.

$$F_{Total} = \frac{P_T Loss + \mu}{MVA_{base}} \tag{4.11}$$

To normalized the total power loss MVAbase and μ are introduced which take a value between (0,1) which is stated earlier.

$$PLDi\%(j) = \frac{PL(j) - PL\max}{PL(j) - PL\min} \times 100 \qquad (4.12)$$

Where; PLDi (j), PLmax and PLmin are the power loss index at bus j, power loss rejects at bus j, maximum power loss rejects and minimum power reject. The power loss index in equation (4.12) is most likely to identify our DGs placement.

4.2.4 Constraints

The constraints imposed here is to solve the problems associated with optimal placement and sizing the DG in the distribution system. The bus cumulative magnitude voltage deviation (CVD) must be kept at a normalized value within specified limits at each particular bus as defined below.

$$CVD = \left\{ \sum_{j=1}^{NDG'S} (1 - vi) \text{, if } 0.95 \le vi \le 1.05 \right\} \qquad (4.13)$$

The minimum of (0.95pu) and maximum of (1.05pu) voltage magnitude of each bus should be within the given limits

$$V_{\min} \le V \le V_{(\max)}$$

$$\left| I_{K,K+1} \right| \ge I_{K,K+1(\max)} \qquad (4.14)$$

Equation (4.14) defines current limits carrying the line section between the buses of $K \; and \; K + 1$.

The current limits of the branches should be noted that they are not explicit and are defined by the IEEE bus.

Power flow constraints satisfaction

A simple radial feeder configuration is represented by the single line diagram in Fig. 4.1. Power flow is computed with the aid of the following set of equations taking from (‘Ekpa, T. K. 1*, Sani, S.2, Hasssan, A. S.3 and Kalyankolo, Z.4 1,Journal of the Nigerian Association of

Mathematical Physics Volume 48 (Sept. & Nov., 2018 Issue), pp347-352 © J. of NAMP ON', no date).

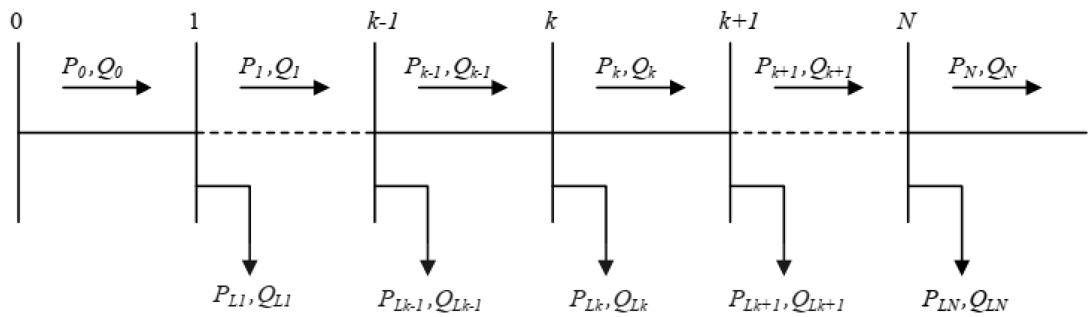


Figure 4.1: Single line diagram of a feeder (Sanjay et al., 2017)

$$P_{K+1} = P_K - P_{LK+1} - R_{K,K+1} \times \frac{PK^2 + QK^2}{|VK| \times |VK|} \tag{4.15}$$

$$Q_{K+1} = Q_K - Q_{LK+1} - Q_{LK+1} - X_{LK+1,L} \times \frac{P^2{}_K + Q^2{}_K}{|V_K|^2} \tag{4.16}$$

$$|V_{K+1}|^2 = |V_k|^2 - 2 \times \left[(R_{K,K+1} \times P_K + X_{K,K+!} \times Q \right] + \left[R_{K,K+1}{}^2 + X_{K,K+1} \right] \tag{4.17}$$

$$P_{Load} + P_{Loss} = P_{subreal} + \sum_{RDG=1}^{j} PRDG \tag{4.18}$$

$$Q_{Load} + Q_{Loss} = Q_{Subreal} + \sum_{RDG=1}^{j} QRDG \tag{4.19}$$

DG perforation limit

$PRDG \leq PDemand$

Where P_K the real power and Q_K is the reactive power flowing through the bus K P_{LK+1} is the real power demand, while Q_{LK+1} is the reactive demand load at the peculiar bus called K+1. Reactance and resistance of the line are $X_{K,K+1}$ and $R_{K,K+1}$. $|V_K|$, Is the magnitude of the voltage at the K bus. However, Equ (4.18) and Equ (4.19) provide line losses connecting the bus Q.

The above constraints must always satisfy in the distribution network system, otherwise rejected.

4.2.5 Overall system Efficiency

To calculate the total efficiency η_{System} of the proposed system RDG in this work, we apply the concept of efficiency model in ('Ekpa, T. K. 1*, Sani, S.2, Hasssan, A. S.3 and Kalyankolo, Z.4 1,Journal of the Nigerian Association of Mathematical Physics Volume 48 (Sept. & Nov., 2018 Issue), pp347-352 © J. of NAMP ON', no date). We let $\eta_{j,j=1,2,....n}$ denotes the component efficiencies for a given system with j components. Then the overall system energy efficiency η_{System} is given by

$$\eta_{System} = \prod \eta_{j-k} \tag{4.20}$$

4.3 Distributed Energy Resources Modelling (DER)

For the planning of various kinds of Renewable energy sources (RES), three (3) different optimization formulations have been adopted. The objectives used in this optimization techniques are considered as maximization of energy utilization of Gas turbine, photo-voltaic system (PV) and wind turbine generation. The formulation is based on water, energy and food techniques adopted by having eight possible points to position our DGs within a given distribution network system.

4.3.1 Problem formulation for Proposed Algorithm

The proposed Algorithm here, tells how the energy is utilized or under-utilized in a distribution network. The Algorithm predicts the state of an object relative to its usage at any given number of elements within the network system. However, this model is deployed to address global problems related to allocating multiple DGs in a given network system. This model has eight (8) possible coordinates to fix an object in a given network system, thereby minimizing energy loss.

The WEF model design for the allocation of the hybrid Renewable energy-based DG has some unique properties if fixed within the distribution network nodes.

1. It has an infinite number of solutions and this has made it simple to fix our DG in many points within the Distribution system.
2. A probabilistic solution generates several solutions for the whole WEF Renewable hybrid DG, thereby providing an optimal solution to minimize energy loss.

Here we assumed a state of three elements (water, energy, and food) that are interdependent to one another. However, these three states will form a natural communicating Markov as proposed in (Sulaiman Sani *et al.*, 2019). The following notations are adopted:

β: Denotes the constant values of the energy in wind

γ: Denotes the constant values of solar energy

$\alpha: Denotes\ the\ fuel\ cell\ energy\ constants$

$\rho\ : Probabilitymeasuresontheenergyspacefor the 3DG's\ such\ that\ Ei(:)i = 0,1$

$\mu = rate\ at\ which\ an\ elecemnt\ is\ used\ in\ the\ Distribution\ system$

$L : The\ state\ of\ \ wind\ energy\ DG\ in\ a\ Distribution\ System$

$i : The\ state\ of\ solar\ energy\ DG\ in\ a\ Distribution\ network\ system$

$j : The\ state\ of\ fuel\ energy\ DG\ \ in\ a\ Distribution\ network\ system.$

P 0, 0, 0: probability measure allocation of the DG's is maximum utilized in the distribution network.

P 1, 0, 0: probability measure that wind energy is maximum utilized, solar and gas turbines are minima utilized.

P 0, 1, 0: probability measure that solar is maximum utilized, while wind and gas turbines are minima utilized.

P 0, 0, 1: probability measure that gas turbine is maximum utilized, while solar and wind energy is minimum utilized.

P 1, 1, 0: probability measure that both solar and wind energy are maximum utilized, while gas turbine is minimum utilized.

P 0, 1, 1: probability measure that wind and gas turbines are maximum utilized, while solar energy is under-utilized.

P 0, 0, 1: probability measure that gas turbine is maximum utilized, while solar and wind energy is under-utilized.

P 1, 1, 1: probability measure that the 3 DG's are maximum utilized

In General

$$Ei = hc \sum Pi \quad (4.21)$$

E- Energy at [P 0,0,0], [P 1,0,0], [P 0,1,0], , [P 1,1,0] ,[P 1,0,1], [P 0,1,1], [P 0,0,1], [P1,1,1,].

$$Emax\ is\ the\ monoticity\ , for\ the\ Emax\ to\ hold\ \ Ei > Ej$$

4.3.2 Objective Functions Formulations

Case A: Minimization of wind energy

$$E(w) = E0,1,0(w) + E0,1,1(w) + E1,1,0(w) + E1,1,1(w) \quad (4.22)$$

Case B: Minimization of the solar PV system

$$E2(s) = E1,0,0(s) + E1,1,0(s) + E1,0,1(s) + E1,1,1(s) \quad (4.23)$$

Case C: Minimization of Gas Turbine energy system

$$E3 = E0,0,1(f) + E0,1,1(f) + E1,0,1(f) + E1,1,1(f) \quad (4.24)$$

4.3.3 Wind speed Modeling and Power output

The real output power of the wind DG based is always immensely influenced by wind speed. Therefore, before the placement of these energy sources in the distribution system the uncertainty related to the speed of the energy is modeled. The wind power function is taken from (Sarkar and Behera, 2012).

$$P_{Wind} = 0.5\rho ACpNgNb \quad (4.25)$$

Here $Cp = Coefficient\ of\ performance$

$g = generator\ efficiency$

$Nb = gear\ box\ efficiency$

$\rho = density$

$A = Area$

Let P be a probability of measure on the energy space for the wind DG, such that

$\{Ei(:)\ : i = 0,1\}$

$P(E1(w)) = probability$ that wind DG energy is at maximum

Application of the model, by (Sulaiman Sani *et al.*, 2019), for a DG to attained maximum it must certify the Lagrangian function. By Hamilton's variation principle on Equ (4.22), the probability of the total energy is given by Lagrangian function along the extreme path (maximum or minimum) compared to the nearby variation.

$$\int_0^1 0.5\delta ANg\rho\partial\rho \quad (4.26)$$

We assume $CP \rightarrow \rho$

$$\int_0^\infty A\ Ng\ Nb\ f(\rho)\partial\rho = P(E0,1,0) + P(E0,1,1) + P(E,1,1,0) + P(E1,1,1)(4) \quad (4.27)$$

We assume $\beta = o.5\delta ANgNb$

Where $F(\rho)$ $is\ the\ Langranrian\ function$

$$(\rho, w) = \beta\int_0^\infty f(\rho)\partial\rho = \frac{\pi\rho}{(1+\rho)^3(1+\pi+\pi^2)} + \frac{\pi\rho(\pi+1)}{(1+\rho)^3(1+\pi+\pi^2)} + \frac{\rho(\pi+1)}{(1+\rho)^3(1+\pi+\pi^2)} + \frac{\rho^3}{(1+\rho^3)}$$

(4.28)

Given equation (4.25), (4.26), (4.27) and (4.28), and upon applying Quotient rule on the equation (4.28), and differentiating with respect to ρ one obtains equation (4.29) as follows

$$f(\rho, w) = \pi(\pi^2 + \pi + 1)(\rho(\rho + 2\pi + 4) - \pi - 3/(\rho + 1)^4 + {}^{3\rho^2}\!\big/_{(\rho+1)^4} \qquad (4.28)$$

$$= \frac{(3\pi^2 + 2\pi + 3)\rho^2 - 2\pi(\pi + 2)\rho + \pi + 3\pi}{(\pi^2 + \pi + 1)(\rho + 1)^4} \qquad (4.29)$$

For numerical approximation to illustrate the behavior of $F(\rho, w)$ with the utilization parameterρ, we assume that ρ varies from 0.0010 to 0.9999. The numerical result for the behavior is obtained in table 1. It is observed from Table 1, the state probability generated for the wind values of the probability $f(\rho, w)$ decreases as the utilization rates ρ increases which is expected.

Table 4.1: Results for the first scenario of rho in D.S type one

ρ	$f\ (\rho, w)$
0.0010	0.730322055
0.1250	0.706831639
0.2990	0.358818766
0.4753	0.191723776
0.8111	0.182632786
0.9000	0.178659698

0.9999	0.175479984

Table4. 2: Results for the second scenario (rho, solar) in D.S type two

ρ	$f\ (\rho, w)$
0.0010	0.730322055
0.1250	0.619125122
0.2990	0.469749681
0.4753	0.566307961
0.8111	0.775099677
0.9000	0.649395187
0.9999	0.799201072

Table 4. 3: Results for third scenario (solar, wind and Gas Turbine) in D.S type three

ρ	P1,0,0	P0,10	P0,0,1
0.0010	0.000071229	0.000005508	0.000991467
0.1250	0.000704904	0.000485012	0.087301243
0.2990	0.012646712	0.000753622	0.135657349
0.4753	0.015585902	0.0000817815	0.147200031
0.8111	0.017648764	0.000754350	0.135782257
0.9000	0.017793446	0.000724923	0.130490012
0.9999	0.017842872	0.000690621	0.124315576

4.3.4 Solar PV Modeling and Power output calculation.

The output power of solar PV is sporadic, because of its irregular nature of solar irradiance. So, determine the exact output power from these sources and model the solar irradiance effectively. For these different probability distribution functions (PDF) are used, but the beta PDF is appropriate for modeling solar irradiance (Sarkar and Behera, 2012) and (Bawazir and Cetin, 2020). The equation is obtained by the beta distribution function.

$$fb_S = \frac{\Gamma(\alpha_a + \beta_b)}{\Gamma(\alpha_a)\Gamma(\beta_a)} S^{\alpha a-1}(1-S)\beta^{a-1} \, for \, \alpha_a > 0; \beta_a . > 0 \tag{4.30}$$

Here;

$$S = Solar\ irridiance\ in \frac{KW}{M^2};$$

$$fb_{(S)} = Beta\ distribution\ of\ s$$

$$\alpha\ and\ \beta\ are\ \ parameters\ of\ the\ beta\ distribution\ function$$

To obtain the modeling for the output power, we need to keep in mind that the PV module is affected by the solar irradiance and ambient temperature of the location as well as changes that occur in the modules during operations. This modeled equation is taken from (Sarkar and Behera, 2012).

$$P\_(DGSolar = N \times FF \times IP \times VP) \tag{4.31}$$

Here,

$$FF = \frac{VmmP \times ImmP}{Voc \times Isc} \tag{4.32}$$

$$FF = fil\ factor\ , Range\ of\ 0.83max$$

$$IP = current\ parameters$$

$$VP = Voltage\ Parameters$$

$$N = total\ number\ of\ pv\ modules$$

This implies that equation (4.31), can be re-written as

$$P_{DGsolar} = a \times N \times \rho \times IP \times Vp \tag{4.33}$$

$$a \times \rho = 0.83$$

$$a \leq 0.83$$

$$let\ p\ be\ a\ probability\ measure\ of\ the\ energy\ space\ of\ the\ solar\ DG\ at\ max$$

$p(E2(s))$ is the probability measure of the DG energy in space.

By applying the model concept, one obtains the equation below;

$$E2(s) = \int^{\infty} 0.83 N\rho IPVP\delta\rho \tag{4.34}$$

We assume a=0.83, equation (4.34) can be re-written as follows

$$\int_0^{\infty} aN\rho IPVp\delta\rho = E1{,}0{,}0(s) + E1{,}1{,}0(s) + E1{,}0{,}1(s) + E1{,}1{,}1(s) \tag{4.35}$$

$$let\ \gamma = aNIPVP$$

$$\gamma \int_0^{\infty} f(\rho)\delta\rho = \frac{\rho}{(1+\rho^3)(1+\pi+\pi^2)} + \frac{\rho(\pi+1)}{(1+\rho)^3(1+\pi+\pi^2)} + \frac{\rho(\pi^2+1)}{(1+\rho)^3(1+\pi+\pi^2)} + \frac{\rho^3}{1+\rho^3} \tag{4.36}$$

Differentiating equation (36), with respect to ρ, one obtains equation (37) as follows

$$\frac{1-2\rho^3}{(\pi+\pi^2+1)} + \frac{(\pi^2+\pi+2)(\rho+1)^3 - 3(\rho+1)^2((\pi^2+1)\rho+(\pi+1)\rho)+}{(\pi^2+\pi+1)(\rho+1)^6} \frac{3\rho^2(\rho^3+1)-3\rho^5}{(\rho^3+1)^2} \tag{4.37}$$

4.3.5 Minimization of Emission

Generating electrical power from conventional energy sources emits harmful gases into our environment. The amounts in tones per hour (t/hour) of common pollutant considered in the research work are; carbon monoxide (Co), nitrogen oxides(No_x), Sulfur dioxide (So_2) and volatile organic compoundsVoc (Hassan, Sun and Wang, 2020).

$$F(x,u) = E = \sum_{i=1}^{NG} [\ \varphi i + \psi ipgi + wipgi^2) \times 0.01 + \tau i \times \exp(\xi pgi) \tag{4.38}$$

$$\sum_{i=1}^{NOGAST} EGASTi + \sum_{i}^{NOPVA} EPVAi + \sum_{i=1}^{NOWindi} EWindTi + EGrid \tag{4.39}$$

$$EGASTi = (Nox)^{GAST} + (CO)^{GAST} + (SO_2)^{GAST} + (Voc)^{GAST} \text{ XPGTI} \tag{4.40}$$

Where, φi, ψi, ωi, τi, and ζi are all emission coefficients associated with the i-th thermal generator.

$$EPVAI = (Co_2)^{PVA} + (No_x)^{PVA} + (So_2)^{PVA} \times PpVA \tag{4.41}$$

$$EWTi = (Co_2)^{WT} + (No_x)^{WT} + (So_2)^{WT} + (Voc)^{WT} \times PWTi \tag{4.42}$$

$$EGrid = (Co_2{}^{Grid} + No_x{}^{Grid} + So_x{}^{Grid} + Voc^{Grid} + E^{Grid}{}_{Power}) \tag{4.43}$$

Were E and $EPGrid$, are control design parameters for the emissions produced by this energy sources and electrical power generated at ith energy sources. Gas turbines, Wind turbines, Solar Pv and Grid (Hassan, Sun and Wang, 2020)

4.3.6 Minimization of Cost

Total cost in wind energy (Singh and Parida, no date)

$$C_{Wind} = \frac{(FCR \times ICC)}{AEP} + OM + MC \tag{4.44}$$

Here;

FCR= is a percentage of the cost of installed capital cost including debt service. Fixed charge rate.

ICC= The initial capital cost is obtained as the sum of the cost of the wind power system and the cost structure of the wind position.

$$AEP_{net} = AEP_{gross} \times Availability \times (1 - losses) \tag{4.45}$$

$AEP_{gross} =$ Annual energy production

OM+MC= is the operating and maintenance cost

From equ. (4.46), the cost of generating solar power includes investment, power electronic device interfaces, maintenance, operation and installation costs.

The total cost of photovoltaic panels

$$Cost_{PV} = C_{inv,PV} + C_{M\&O} + C_{ins,PV} + C_{SolarpanelPv} \tag{4.46}$$

C_{in} = Cost of investment

$C_{O\&M}$ = Cost of operation and maintenance

C_{inst} = Cost of installments

$C_{SollarPV}$ = Solar panel cost ($/w)

Total cost for Conventional gas (Singh and Parida, no date)

$$C_f = \frac{\gamma_{ng}}{\eta} \times P_{dg} + OM \tag{4.47}$$

C_f = Capacity factor

γ_{ng} = Price of natural gas

η = Electrical efficiency

P_{dg} = DG generated power

4.4 Application of dragonfly to determine the optimal size of the distributed energy resources

DFA algorithm starts by creating random expression for a particular optimization process as proposed by (Mirjalili, 2016). The concept of DFA is effectively applied in this work for solving the best location and sizes of these renewable energy sources based on DG. The steps and positions of the dragonflies are triggers by random values defined by the upper and lower case in the defined boundaries. The steps for solving this DG allocation problem of sizing can be illustrated using the pseudo-codes step giving in the figure below **in table 4.4**

Table 4.4: Application of dragonfly to determine the optimal size of the distributed energy resources

Initialize the dragonflies' population such as Xi (1, 2, 3……. n)

Initialize the step vectors ΔX_i (i = 1, 2 …n) using equ (1) and equ (2)

While the requirement for end conditions not satisfied

Compute the objective conditions for all dragonflies

Update the food source and enemy present

Update the values of (k, v, c, f, and e) defined earlier

Compute the values of Ki, Vi, Ci, fi, and Ei using equs (6) to (7)

Update the nearest radius

If a dragonfly has at least a single nearest dragonfly

Update the state vector velocity using equ (6)

Update the vector position using equ (7)

else

Update position vector using equ (8)

end if

The new positions are within the defined boundaries

end while

4.5 Flowchart for configuration

WEF is used in the reconfiguration of the distribution system and it decides the operation of the DG's by providing eight (8) possible ways to position the DG in DN. However, this problem lies in two states of [0, 1]. The binary values of 0 and 1 signify the performance of the DG'S. The flowchart that handles the Algorithm selected for this work is given in **figure 4**.3.

4.6 NUMERICAL SIMULATIONS AND VALIDATION APPROXIMATIONS

4.6.1 33-bus test system

For numerical simulations and validation of the WEF Algorithm designed in this work. The optimal location of the Gas turbine, wind turbines, solar, and their settings is to optimize the objective function as discussed above. The objective function that was considered Cumulative voltage deviation (CVD), total power loss, overall efficiency, and total emissions produced by this conventional gas system and cost minimization of the energy sources. The proposed method is applied to the 33-bus system as shown figure below. The system is connected to the main substation of 132/12.66KV and consists of 32 branches/lines and 33 buses with the size of load at 3.715MW and 2.300MVar. All these data of the line and buses are taken from (Kashem *et al.*, no date), as shown in Fig 2. The block diagram for the optimal placement in IEEE 33 bus system with DG and Without DG is shown in Fig.4.2. fig 4.4 represent the block diagram for the DG allocation of the proposed system.

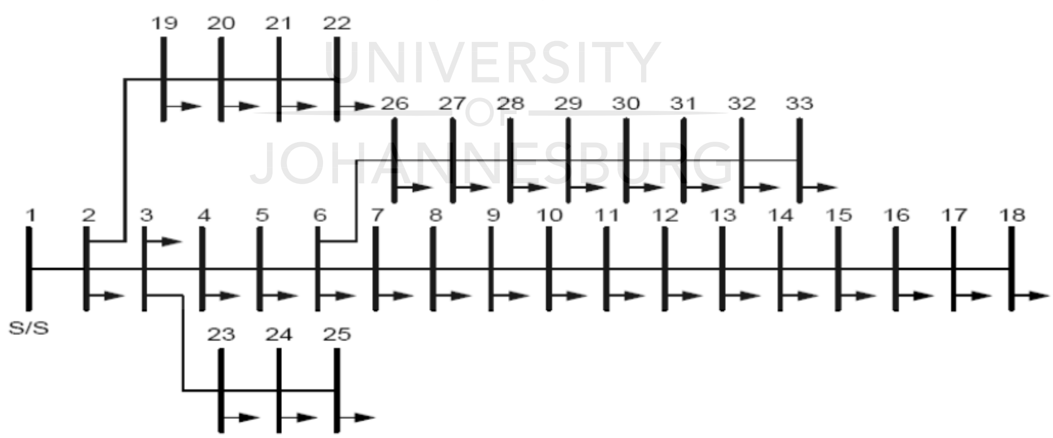


Fig 4.2: A case study of the 33-bus system under study (Moradi, 2010)

Table 4.5: Result obtained for the case study

	CASE1	CASE2	CASE3	CASE4	CASE5
DG CAPACITY IN (MW)	0.5,0.65,0.7	0.6,0.63,0.8	0.4,0.5.0.75	0.50,0.55,0.7	0.6,0.63.0.65
LOCATION OF BUS NUMBER	31,15,9	31,9,15	25,16,11	25,11,16	31,16,11
MAXMIUM POWER LOSS (KW)	84.60	79.20	81.03	86.0	85.4
VOLTAGE PROFILE IMPROVEMENT	0.17548	0.17866	0.18263	0.1972	0.1407
STABILITY INDEX	1.146	1.1345	1.156	1.1713	1.173
UTILIZATION RATE	3.9E-06	0.0354	0.1256	0.4542	0.5635
EMISSION(IB/h)	2046.18	1160.23	2303.67	4606.44	320.65

5.2 Results and Discussion

The major aim of this simulation is to locate three various DG with different sizes. The result obtained from the five (5) cases were summarized below in Table 4.5 and a comparison was carried out in **Table 5.1** to show the effectiveness of the new Algorithm. The DG capacity for all cases was considered to range from a minimum value of 0.5MW to a maximum value of 0.8. In the case of table4, we have calculated the maximum DG capacity as 0.5, 0.65, and 0.70 by placing this DG at positions 31, 15, and 9. However, the best cases among all cases consider are case 2, which is having a value ranging from 0.60-0.80 in terms of losses and located at bus 31, 15, and 9.There is a strong significance in terms of voltage profile improvement.

In DG type one, from table 4.1, Gas turbine usage is highly connected to solar usage at a low occupation rate. Similarly, the Gas turbine is connected to wind energy at a high occupation rate.

It can be seen when $\rho \rightarrow 0.100$ and $\rho \rightarrow 0.1250$, the rotational value for the algorithm does not show much difference between each other. This implies that there is a strong relationship between having Gas turbine DG and solar DG based at an idle state of operation in comparison to the other point.

In DG type two, occupying Gas turbine and Wind energy is similar to occupying Solar and wind DG position. This is evident from table 4.2 above. One can see that if ρ *approaches* 0.999 from below, the values of $\rho \rightarrow 0.0010$ and $\rho \rightarrow 0.9999$ are approximately the same. Consequently, the busy periods of the two states DG are equivalent. At this stage we assume the allocation is at idle state and no losses will be recorded, hence placement is at the right position.

In DG type three, from the view of **table 4.3**, there is a high rate of occupying all the best positions from the results obtained. The parameters considered for DFA for both the test systems are number of search agents=20, dimension of search space (d=5), separation weight(s=0.1), alignment weight (a=0.1), cohesion weight (c=0.7), food attraction weight (f=1), enemy distraction weight (e=1) and inertia weight (w=0.9) and maximum number of iterations=100. The base case voltages for the allocation values in each bus are presented in **Figure 6,** while **Table 6** compares the results of the various methods for the test systems for the allocation of a single DG unit, two DG units, and three DG units. The comparison is carried out concerning the DG locations, DG sizes, and RPL.

Table 5.1: Compares the results of the various methods for the test systems for the allocation of a single and multiple DG unit

Method	DG location bus number/bus location	Voltage (p.u)	Power loss (kW)
Genetic Algorithm (GA) (Moradi, 2010)	GA PSO 6 13 24 30 0.6429 0.8571 0.8571 0.7382	0.9703	0.0682
BFOA (Imran, no date)	0.542 (17), 0.160 (18), 0.895 (33)	0.978	41.41
GA (Saonerkar and Bagde, B Y, 2014)	0.25 (16), 0.25 (22), 0.50 (30)	0.971	71.25

WEF Case 1, 2 and 3	31 15 9 0.50 0.65 0.70	0.9622*	21.57*

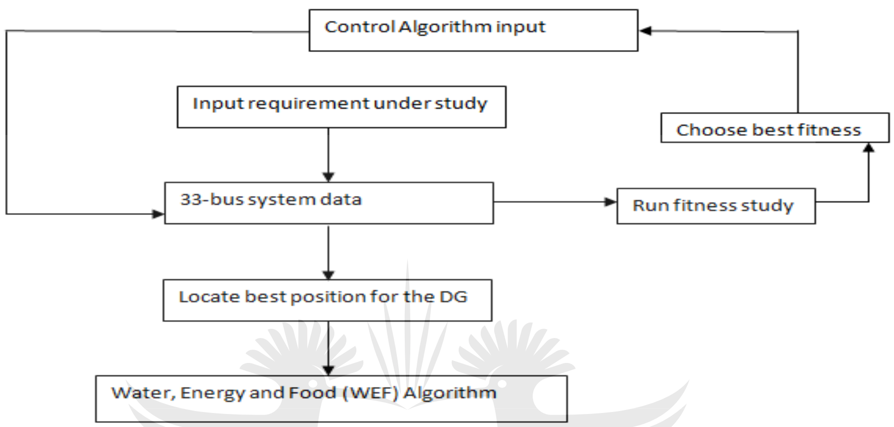
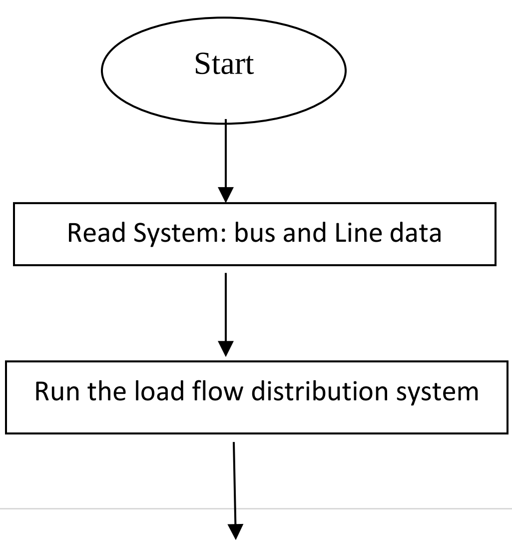


Fig 4.4: Block diagram for allocation of DG



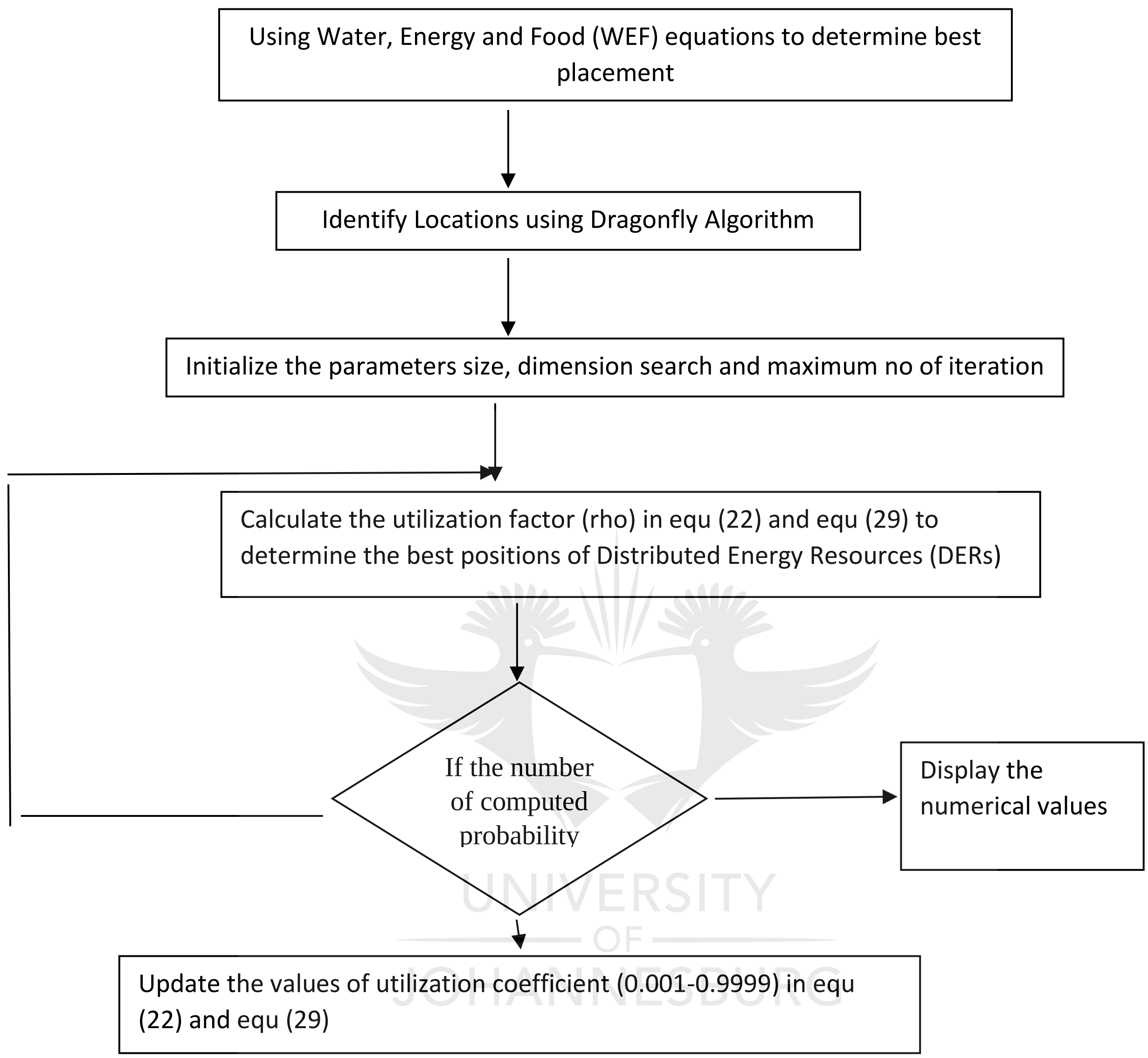


Figure 4.3: Optimal DG allocation methodology

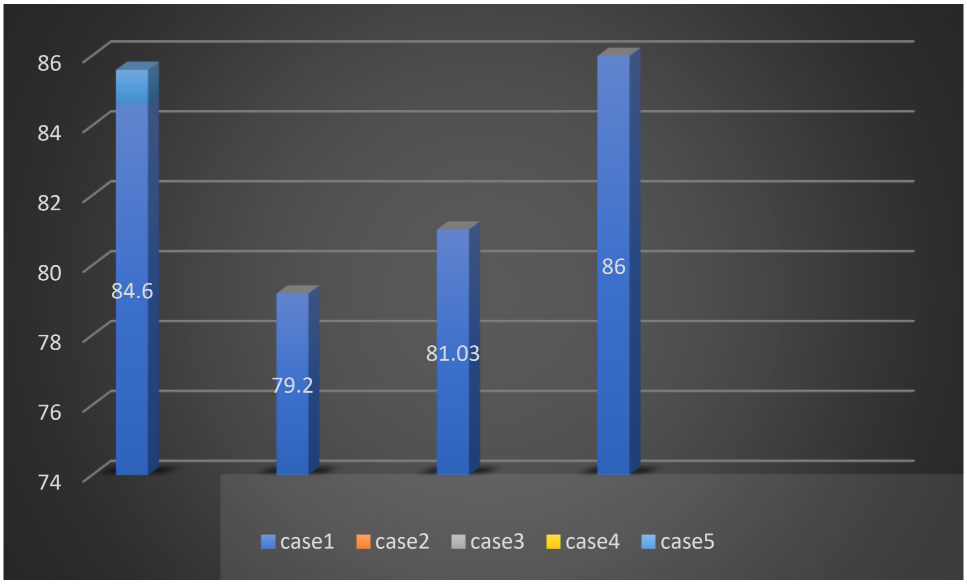


Figure 4.5A: Result of objective function in terms of power loss reduction with installation of DG system

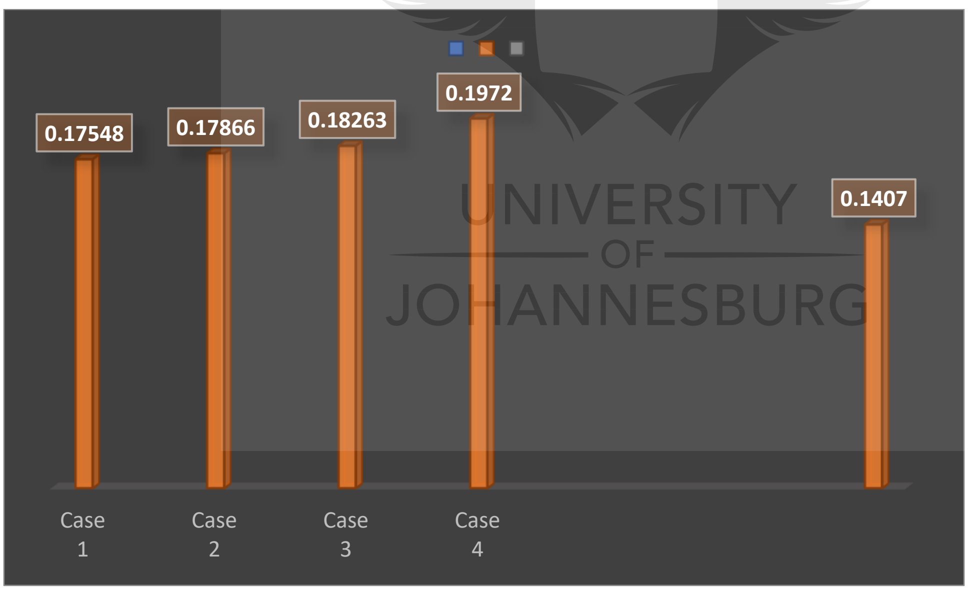


Fig 4.5B: Result of voltage profile improvement with installation of DG System

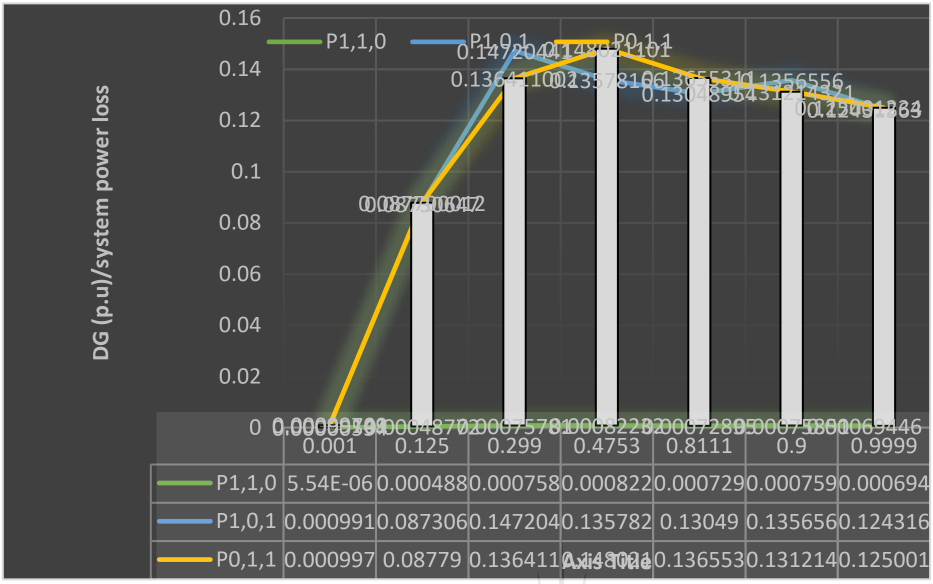


Fig 4.5C: DG size, Bus location & System power loss of 33-bus test system

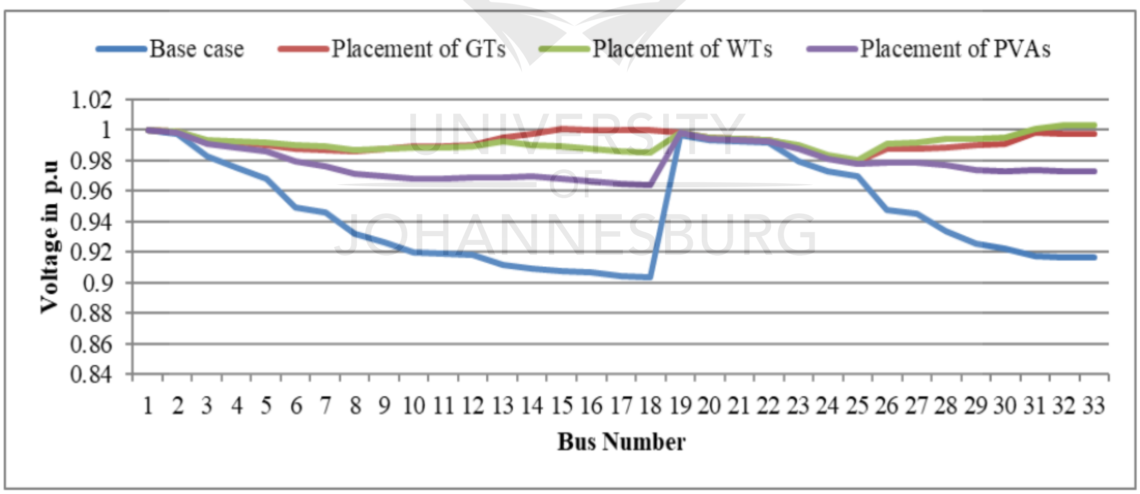


Fig4.6: Voltage profile of 33 bus test system with optimal allocation of GTs, WTs, and PVAs placed in DS

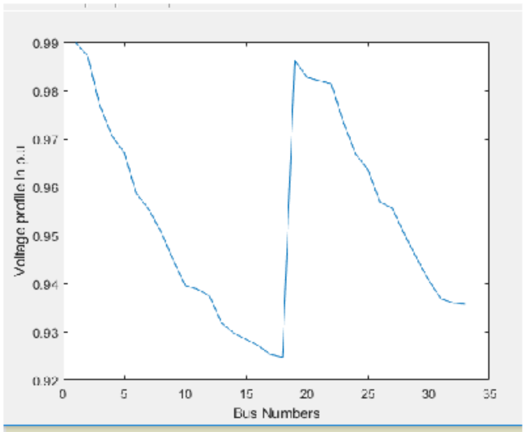


Figure 7A: Voltage profile of 33 bus test system without DG

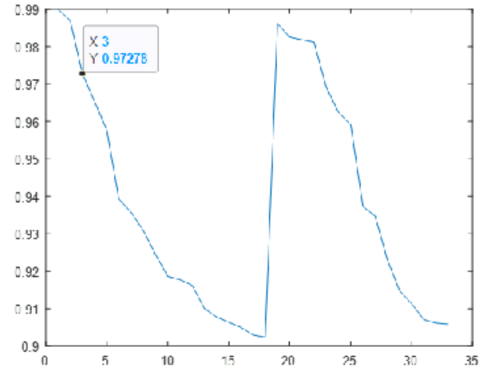


Figure 7B: Voltage profile 33-bus system considering placement of DG'S type two

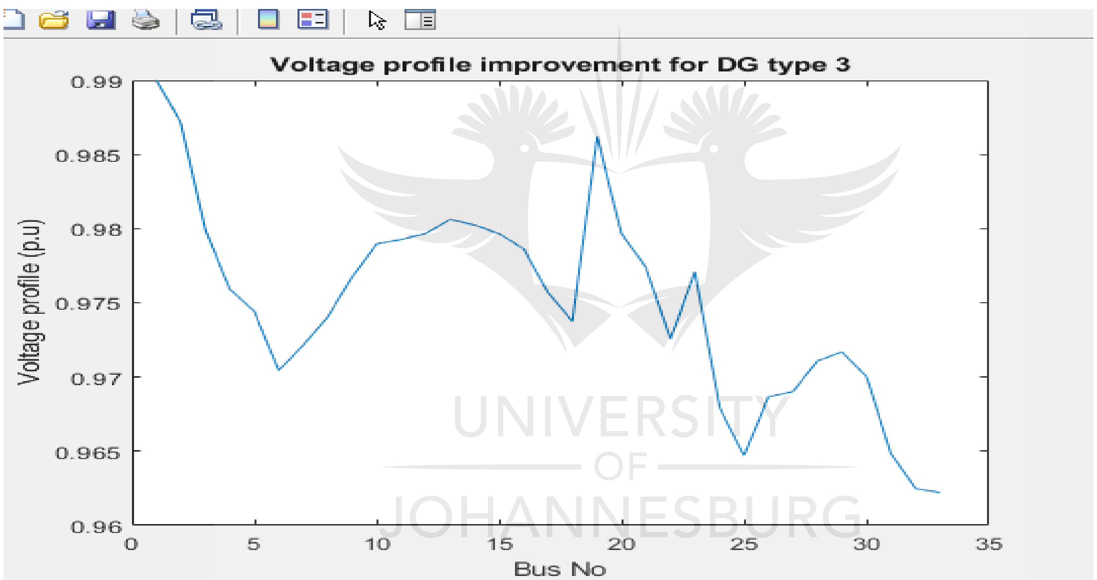


Figure 7C: Voltage profile 33-bus system considering placement of DG'S type three

Table 5.2: Power loss comparison considering Case study with DG and without DG

	Active power loss
Base model without a Gas turbine, Wind DG and Solar PV	Power-Loss=2.067320e+02 KW, Power-Loss=1.379097e+02 KVAr'
The base model with the Gas turbine, wind DG and Solar PV	Power Loss=$1.115737X10^{2}KW$, Power Loss=$7.293871X10^{1}KVAr$ DG1 Power = 8.738701e+02 DG2 power=1.310805e+03 DG3 Power = 8.738701e+02

5.3 Power Losses

Table 5.2, presents a comparison of real and reactive power losses before and after reconfiguration and DG placement in the distribution network. Losses minimized throughout the 1st, 2nd, and 3rd intervals are up to 21.57 when compared to that (Esmaeilian and Fadaeinedjad, 2014).

5.4 CONCLUSIONS

Most algorithms proposed in the literature by various authors to solve optimal DG placement problems consider only location and size as the variables of optimization in minimizing the power loss in a network. However, Renewable Distributed Generations technology also plays an important role in minimizing the loss of the power network. The new methodology proposed to optimally place the Gas turbine, wind DG and Solar PV to minimize the active power loss of the system using WEF has been fully discussed in this paper. Water, Energy, and Food algorithm, is easy to implement and the time taken for the iteration is less compared to other conventional methods and it is accurate. An efficient WEF is used in the optimization process of allocation DG in the distribution system. The developed algorithm successfully optimized the location and size (penetration level) of the DG and determines the appropriate DG technology. It was further shown that the algorithm was able to optimally locate and size more DGs to further reduce losses on the network. The results show that the optimal allocation of the Gas turbine, wind DG and Solar PV will minimize the real power loss as well as the reduction in emission as shown in table 5, and it is tested on IEEE 33- bus system and shows improvement in the Results display minimization in losses up to 70% and remarkable improvement in voltage profile at every load bus.

CHAPTER 5

AN EFFECTIVE PLACEMENT FOR OPTIMAL POWER FLOW WITH THE INCLUSION OF MULTI-FACTS DEVICES.

5.1 INTRODUCTION

Optimal power flow (OPF) vestiges a widely-cultivated topic within electrical power system research domain since its commencement about half-a-decade ago to satisfy the increase in power demand globally (Hassan, Sun and Wang, 2020), and its primary objective is minimization of generation cost with the help of control variables through optimal reconfigurations (Biswas, Suganthan and Amaratunga, 2017). Distributed generation (DG) generates a small fraction of the required electrical energy on a minimal scale closer to the consumer load. Market Liberalization and environmental factors according to (Singh, Mukherjee and Tiwari, 2015), are the two major factors that have contributed to the renewed interest in DGs. However, this renews interest has pushed many researchers to study the optimal placement of DG and flexible AC Transmission (FACTS) in an electrical power system. Using FACTS devices is a very prevalent and mutual method for addressing the mentioned issues in (Gomes and Saraiva, no date; Yang *et al.*, 2007; Zhu *et al.*, 2010; Hong-zhong, Hao-zhong and Zheng, 2010; Jordehi and Jasni, 2011; Badar, Umre and Junghare, 2012; Hooshmand, Hemmati and Parastegari, 2012; Lin, Lin and Horng, 2012; Mahmoudabadi and Rashidinejad, 2013; Farhoodnea *et al.*, 2014; Gandhi and Joshi, 2014; Rao and Vaisakh, 2014). The placement of DG's and FACTS in an optimal location promises in environmental greenhouse gas emission, low power losses, boost voltage stability, load ability, and available power transfer capacity (Singh, Mukherjee and Tiwari, 2015). The potential driver towards DG and FACTS controllers embedded in the distributed energy system always results in numerical simulation during installation. This interaction needs to be studied properly from point of view to avoid frequency deviation and interconnection problems (Mahdad, Bouktir and Srairi, no date).FACTS devices consist of static synchronous series compensator (SSSC), Unified power flow controller (UPFC), thyristor controlled voltage regulator (TCVR), and Static synchronous compensator (STATCOM) (Jordehi and Jasni, 2011). Their various methodology applied to solve optimal power flow problem using FACTS such as; Heuristic methods for the solution of FACTS optimization in the power system (Jordehi and Jasni, 2011), In ref (Chaib *et al.*, 2016), backtracking search optimization algorithm was proposed to solve optimal power flow problem to control cost function and emission. The classical optimization problem was proposed in (Lima *et al.*, 2003; Programming *et al.*, 2007) for FACTS optimization to support optimal power flow, despite achieving excellent results their optimization using facts does not guarantee an optimal solution. A detailed optimization survey of different FACTS controllers was carried out in (Singh and Kumar, 2020) to examine their performance on power system using realistic and static loads. Multi-objective optimal flow problem using the concept of adaptive group search optimization was developed in (Daryani, Hagh and Teimourzadeh, 2016), to improve the security index,

minimization total operation cost as well as transmission losses. (Ahmad and Sirjani, 2019), carried out a detailed review on different metaheuristic optimization adapted by many authors for optimal placement and sizing of multi-FACT type device in power system to improve the overall performance and minimize the losses associated.

(Pratap et al., 2015), proposes an optimization strategy particle swarm optimization (PSO) to solve optimal power flow problem in power system. In our recent paper (Shuaibu, Sun and Wang, 2020), a new methodology ,Binary particle swarm optimization (BPSO)- Shuffled Leap frog Algorithm (SLFA) was implemented for solving optimal placement and sizing DG with aim of reducing losses within the system.

Impact of the present work

The major impact of this research work is the implementation of two FACTS devices such as; Unified power flow controller (UPFC) Static synchronous compensator (STATCOM) and are utilized for the injection of systems power flow and thus to elevate the power flow in terms of various objective functions. The effectiveness of the proposed algorithm system Hybridized Grey wolf optimization (GWO)-Backtracking search algorithm (BSA) is verified for the solution of optimal power flow problem in electrical power system with the inclusion of FACTS devices and tested on standard IEEE 39-bus system with four (4) technical objectives such as (i) Voltage deviation minimization (ii) Fuel cost minimization (iii) Power loss minimization and (iv) Voltage stability improvement using the selected FACTS devices. The outcomes attained are compared with those of the computation algorithm studied in the literature. The proposed GWO-BSA with FACTS gives very amazing result.

Layout of the paper

The rest of this paper is organized as follows. Section 2 explains the methodology and problem formulation of the FACTS device. Section 3 illustrates the mathematical algorithms for the optimal DG placement with FACTS device is discussed in reconfiguration manner. Section 4 describes the simulation results and flowchart algorithm on different case scenarios. Section 5 of this research paper gives a general conclusion.

5.2 MATHEMATICAL FORMULATION OF PROPOSED PROBLEM

In power system planning problem, the active power is considered as a general minimization problem with various constraints defined as follows

$M_{in} \ _{Z(x)}$ (5.1)

Subjected to $U(x) = 0$ (5.2)

$h(x) \leq 0$ (5.3)

Were $Z(x)$ is the objective function

$U(x)$ and $h(x)$ are set as the equality and inequality constraints that must be satisfied.

The equality constraints $U(x)$ are obtained from the power flow equation.

$P_{gi} - Pd_i - \sum_{j=1}^{N} |vi||vj||Yij| \cos(\delta i - \delta j - \delta ij) = 0$ (5.4)

$Qg_i - Qd_i - \sum_{j=1}^{N} |vi||vj||Yij| \sin(\delta i - \delta j - \delta ij) = 0$ (5.5)

The inequality constraint $h(x)$ are generated as physical limits on the power system devices.

Upper and Lower limits for active power

$P_{gi^{min}} \leq P_{gi} \leq P_{gi^{max}}$ (5.6)

The upper and lower limit for reactive power

$Q_{gi^{mun}} \leq Q_{gi} \leq Q_{gi^{max}}$ (5.7)

The control vector and state equivalent variable are defined as(x).

For optimal power flow (OPF), the control variables are active, reactive power, bus voltage, angle, shunt capacitor and transformer tap setting.

The state variables are considered as load voltage and angle

$$F = \sum_{i=1}^{ng} PGen_i + \sum_{i=1}^{n} PDem_i + Ploss \quad (5.8)$$

$$F_T = F_1 + F_2 + F_3 + F_4 + - - - - F_N \quad (5.9)$$

$$\sum_{i=1}^{N}(F_i) \quad (5.10)$$

$$\emptyset = 0 = P_{load} - \sum_{i}^{N} Pi \quad (5.11)$$

The necessary condition for extremely value to achieve the objective function we apply the concept of 1st derivative of Langrange function.

$$f = F_T + \lambda\phi \quad (5.12)$$

In this research paper, four (4) technical objective are proposed as follows;

$OF_1$is the total voltage deviation minimization

The constraints levied here is to solve the problems associated with optimal placement and sizing the DG in the distribution system. The bus cumulative magnitude voltage deviation (CVD) must be kept at a normalized value within specified limits at each particular bus as defined below.

$$CVD = \left\{ \sum_{j=1}^{NDG'S} (1 - vi) \text{, if } 0.95 \leq vi \leq 1.05 \right\} \quad (5.13)$$

The minimum of (0.95pu) and maximum of (1.05pu) voltage magnitude of each bus should be within the given limits

$$V_{\min} \leq V \leq V_{(\max)}$$

$$\left|I_{K,K+1}\right| \geq I_{K,K+1(\max)} \tag{5.14}$$

Equation (5.14), defines current limits carrying the line section between the buses of

$K \; and \; K+1$.

The current limits of the branches should be noted that they are not explicit and are defined by the IEEE bus.

OF_2 is the total generating cost of the fuel units obtained from (Metweely, 2017)

$$OF_2 = \sum_{i=1}^{Ng}(a_i + b_i Pg_i + d_i \, P^2 g_i) + dPa_{ff}(\frac{\$}{hr}) \tag{5.15}$$

Ng is the generating units

Pg_i The power generated at the i^{th} active power unit

$a_{i\,,}b_i \quad and \; d_i$are the cost coefficient at the i^{th} generation

dPa_{ff} is the real injected power to the energy source STATCOM

The equality constraints $U(x)$ are obtained from the power

- Minimization of power loss

$$P_{Lossobj} = f_{cost} \times \mu + f_{Loss} \times \beta \tag{5.16}$$

- Voltage deviation minimization

$$V_{Dobj} = f_{cost} \times \mu + f_{VD} \times \beta \tag{5.17}$$

$\mu \; and \; \beta$ are constant values determined within the test system

$$\mu \leq 0{,}35$$

$$\mu + \beta = 1$$

5.3 GWO-BSA OVERVIEW

The Hybridized Grey wolf optimization (GWO)-Backtracking search algorithm (BSA) is a novel metaheuristic optimization. The chat describing the GWO-BSA Algorithm is given fig 5.2.

5.3.1 Grey wolf optimization (GWO)

Grey Wolf Optimizer (GWO) is a distinctive swarm-intelligence algorithm which is stimulated from the guidance order and hunting mechanism of grey wolves in nature and built based on the behaviors. Grey wolves are considered as apex predators; they have an average group size of 5–12 on average. The control variables on the hierarchy are defined as Alpha ($\propto$), which is the dominating power member among the group, Beta (β) is a subordinating member to $\propto$, while delta (δ) assist in the control of wolves within the hierarchy and are considered to be omega (ω) (Mirjalili, Mohammad and Lewis, 2014; Mittal, Singh and Sohi, 2016, 2016; Azlan *et al.*, 2018). Fig 5.1 below shows the hierarchy control variables for BSA.

5.3.2 Backtracking search algorithm (BSA)

The backtracking search algorithm (BSA) is a new evolutionary optimization algorithm established by (Civicioglu, 2013), for solving the real optimization problem. BSA is a population-based iteration method for global optimizer in the power system. BSA optimizer problem is divided into five (5) distinct groups as shown in fig 5.3.

i. Initialization

repeat

ii.Selection 1

Generation of population trial

iii. Mutation

iv. Crossover

end

v. Selection 2

End once conditions are achieved

Fig 5.1. The general structure of BSA

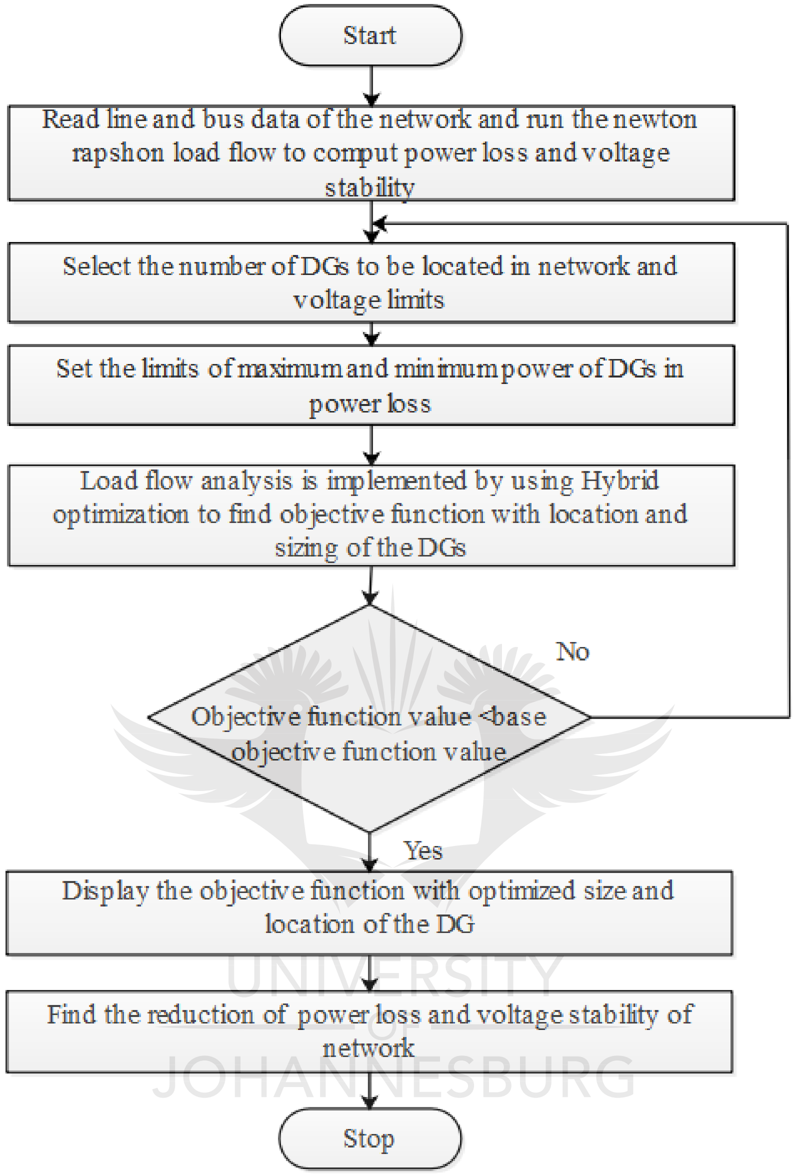


Fig 5.2 A Proposed flowchart for the Algorithm

5.3.3 Modeling of UPFC

Fig.5.4 below represents the schematic diagram of the proposed UPFC, which is capable of providing active and reactive power control variables. The modeling of the UPFC can be summarized regarding the injected power. The FACTS model used in this study is based on representing the controller as a key variable with the firing angle control. Fig. 5.3 shows the basic structure of the multi objective OPF strategy. Table 5.1 shows a comprehensive representation of the inequality constraints.

$$P_{ss} = -b_s rViVj\ \sin(\theta i - \theta j + \gamma) \quad (5.18)$$

$$Q_{ss} = -b_s \mathrm{r} Vi^2(r + 2\cos(\gamma)) + b_s r\ ViVj \cos(\theta i - \theta j + \gamma) \quad (5.19)$$

$$Psr = -P\mathrm{ss} \quad (5.20)$$

$$Qsr = bsrViVj \cos(\theta i - \theta j + \gamma) \quad (5.21)$$

Were,

r = is the radius of the UPFC phase angle.

5.4.3 Modeling of STATCOM with power flow

FACTS devices are classified according generations, STATCOM used in this research belongs to the second generation and it is used for shunt reactive power compensation. The Institute of Electrical Electronics Engineering (IEEE), describe STATCOM devices as static synchronous generator operated as static compensator connected in parallel with its output current and it is independently controlled by the AC system voltage (Metweely, 2017). Fig.5.4 shows the voltage source model of a STATCOM.

The active power is obtained from equ. (5.22)

$$P = V_i * V_{sh} * \frac{1}{X} \sin(\ \delta_i \text{-} \delta sh) \quad (5.22)$$

The reactive power transmitted is obtained from equ. (5.23)

$$Q = \frac{Vi^2}{X} - V_i * V_{\frac{sh}{X}} * \cos(\delta i - \delta sh) \quad (5.23)$$

Vi and Vsh are voltages at the reference nodes, $\delta i - \delta sh$ are the angles between the voltages and X denotes complex impedance. Upon performing some complex operations on equ (5.22) and (5.23) yields equ (5.24) and (5.25).

$$P_{sh} = Vi^2 gsh - V_i * V_{sh}[gsh * \cos(\delta_i - \theta_{sh}) + b_{sh} * cos(\delta_i \text{-} \theta_{sh})] = 0 \quad (5.24)$$

$$Q_{sh} = -Vi^2 bsh - V_i * V_{sh}[gsh * \sin(\delta_i - \theta_{sh}) - b_{sh} * cos(\delta_i \text{-} \theta_{sh})] \quad (5.25)$$

$$\frac{1}{gsh} = jb_{sh} + g_{sh} \quad (5.26)$$

The real and reactive power injected are denoted as P_{sh} and Q_{sh}

The conductance and susceptance of the STATCOM are denoted as b_{sh} and gsh

5.4.4 Implementation of the Grey wolf optimization-Backtracking search Algorithm (GWO-BSA)

This section describes the application of GWO-BSA for solving the multi-objective problem with optimal power flow with the inclusion of FACTS devices. The load flow problem is improved for integrating power injection models of various FACTS selected. During the MATLAB programming of the FACTS device, two FACTS devices were placed one time to accommodate the jacobian matrix with the characteristics of the FACTS.

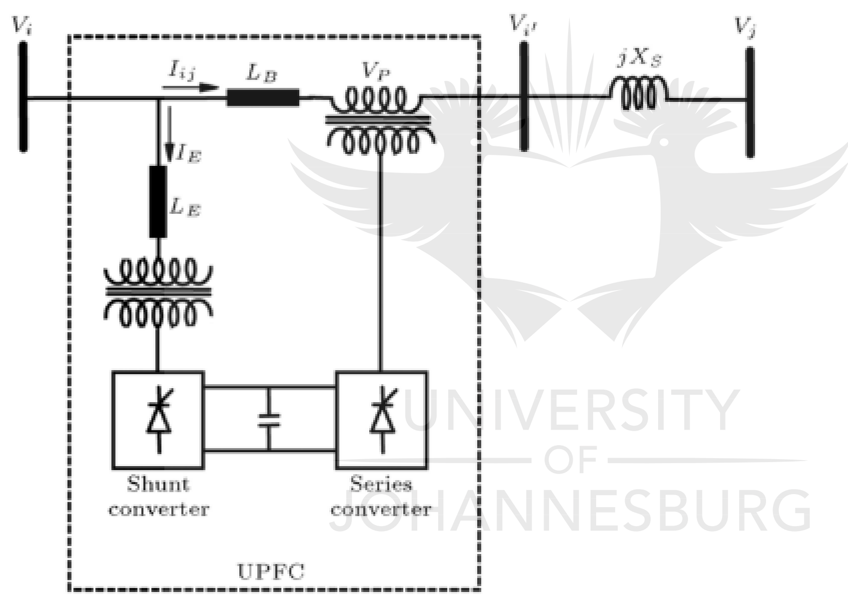


Fig 5.4: Schematic diagram of the proposed UPFC (Kazemi, Rezaeipour and Lashkarara, 2012)

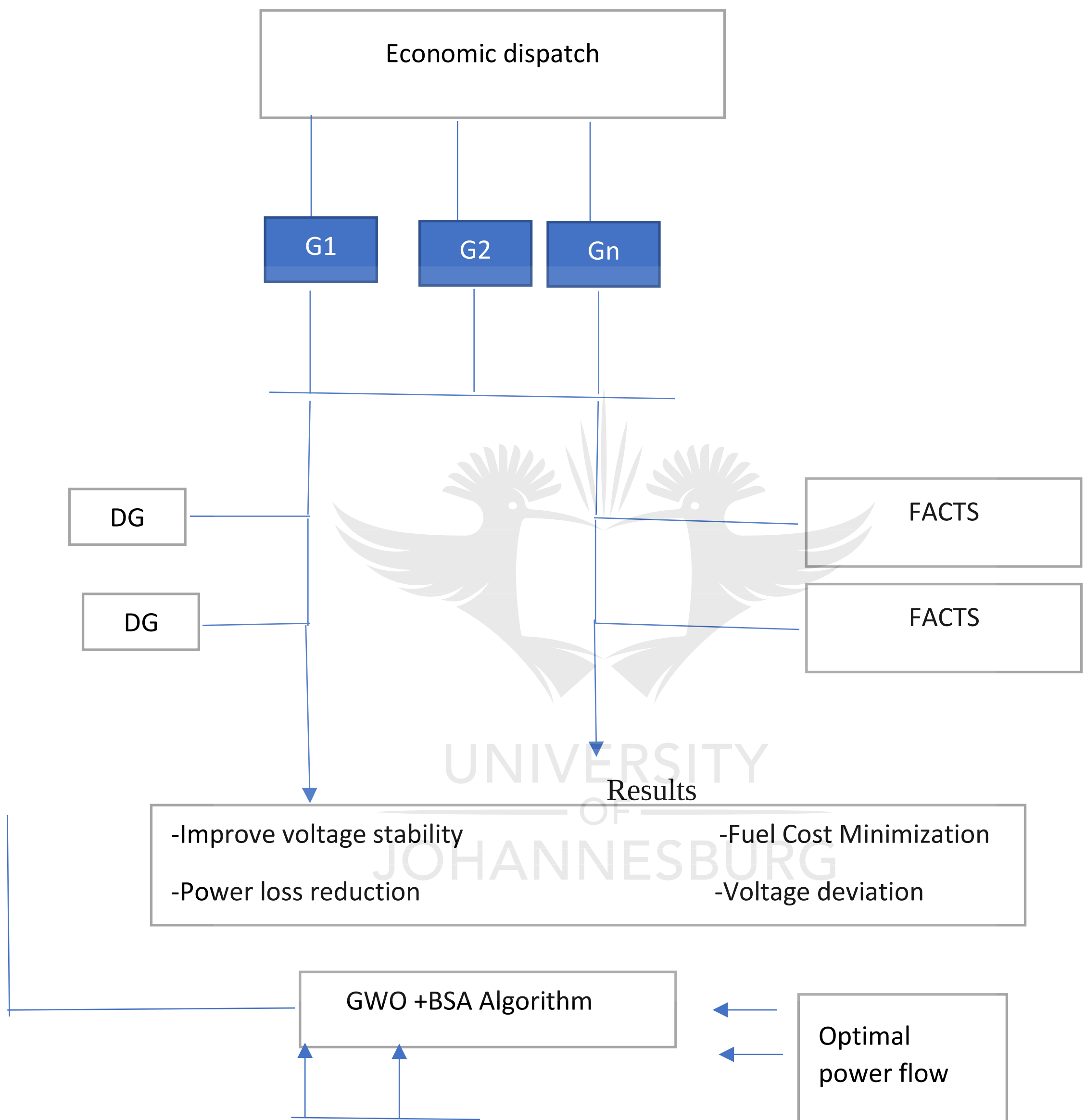


Fig 5.3: Global Strategy of OPF with FACTS and DG

Table 5.1: Broad depiction of real inequality constraints (Mahdad and Srairi, 2014)

Symbols	Elements	Variables	Security margins
P_{gmax} Q_{gmax} $P_{gmin}Q_{gmin}$	Generator	$V_gP_gQ_g$	
$V_{gmin=0.9}V_{gmax=1.06}$			
V_L P_i jQ_i	Load	V_i	
$V_{Lmin=0.95}$ $V_{Lmax=1.1}$			
Z_{ij} S_{ij} $\frac{y}{2}$	Lines	S_{ii}	$S_{ii} \le S^{max}{}_{ii}$
	Transformer Shunt FACTS		$B^{min} \le B^{max}$

Table 5.2: Parameters of optimization for the proposed algorithm for the test system under assessment Test System Balanced 39 bus

Number of heuristics = 5, Min number of eggs = 2, Max number of eggs= 4

Knn cluster = 1, Motion coefficient = 9, Basemva = 100

Number of Iteration = 500

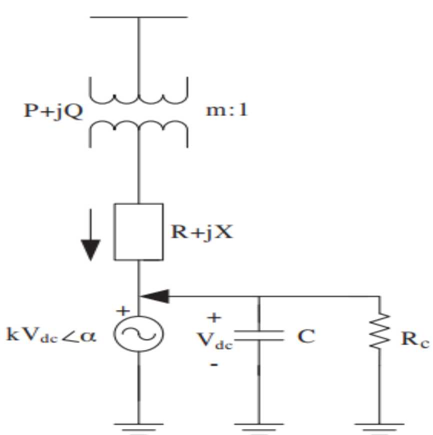


Fig 5.4: Basic configuration of voltage source model of STATCOM (Metweely, 2017)

5.5 Results and case studies

In this research paper, the proposed algorithm GWO-BSA is applied to the IEEE-39 standard test system with the inclusion of FACTS devices installed at a strategic location for solving the optimal power flow problem. Table 5.2 shows the parameters of optimization for the proposed algorithm of the test system. The impacts of these FACTS devices are measured in terms of Voltage stability, voltage deviation index, minimization of real and reactive power losses as well as the cost was studied. The GWO-BSA algorithm is developed in MATLAB programming environment R2019a and the simulation result is run on core i5 Intel with 4GB Ram.

5.5.1 IEEE 39 –bus test system

The performance of STATCOM, UPFC, GWO, and BSA are applied to the IEEE-39 bus test system. The result is explained in table 3 for four objective functions. The IEEE-39 bus system has 10 generators located at node (1-10), 36 transmission lines, 19 loads, and 12 transformer tap changing as shown in fig 5.5. The active and reactive load demands are given as 100MVA, 283.5MW base, and 126.3MVAR.

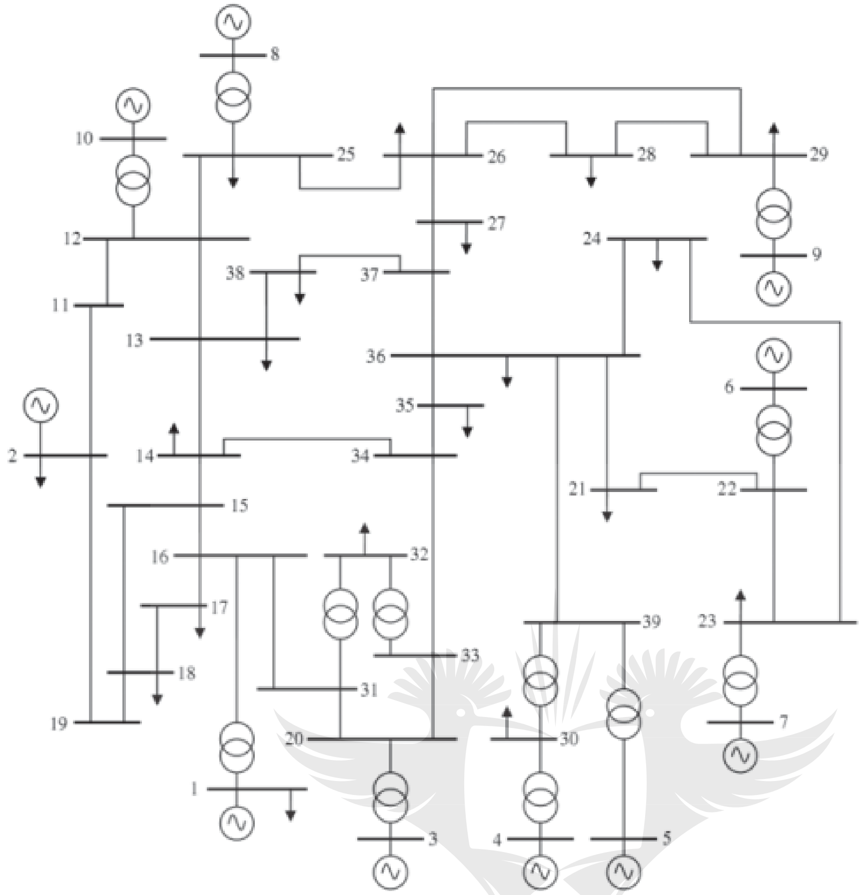


Fig 5.5 IEEE-39 bus test system single line diagram (Perninge and Hamon, 2013)

5.5.2 Objective 1 Minimization of fuel cost

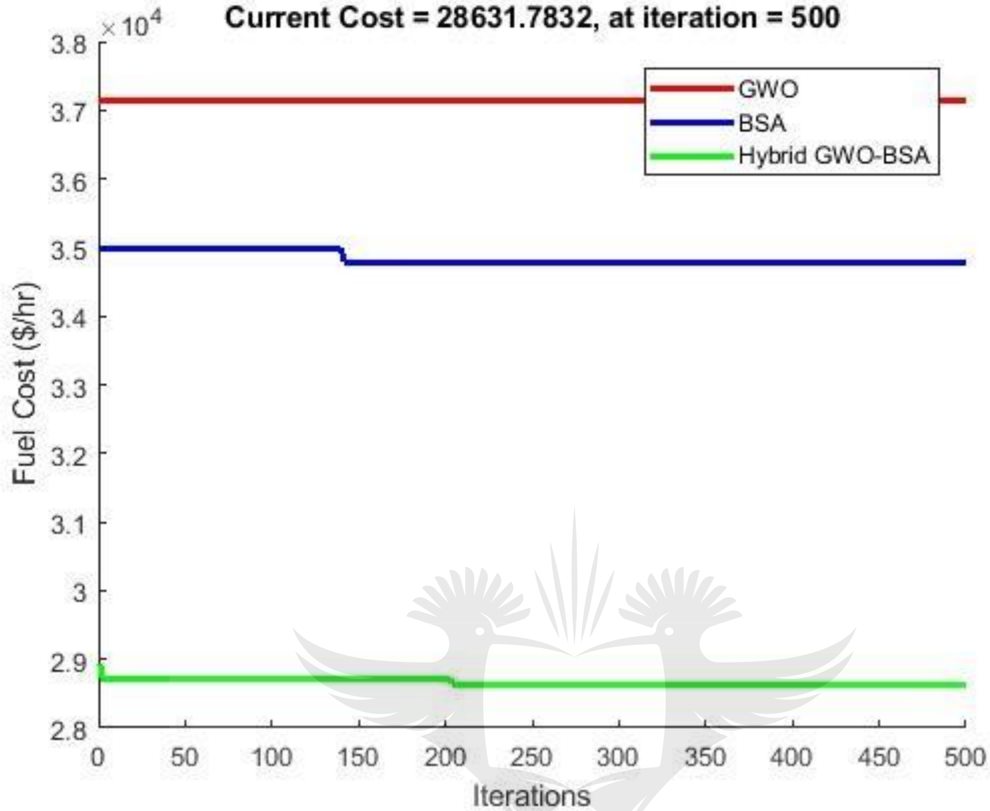


Fig 5.6: Current cost minimization of the proposed system

5.5.3 Objective 2 Real power loss minimization

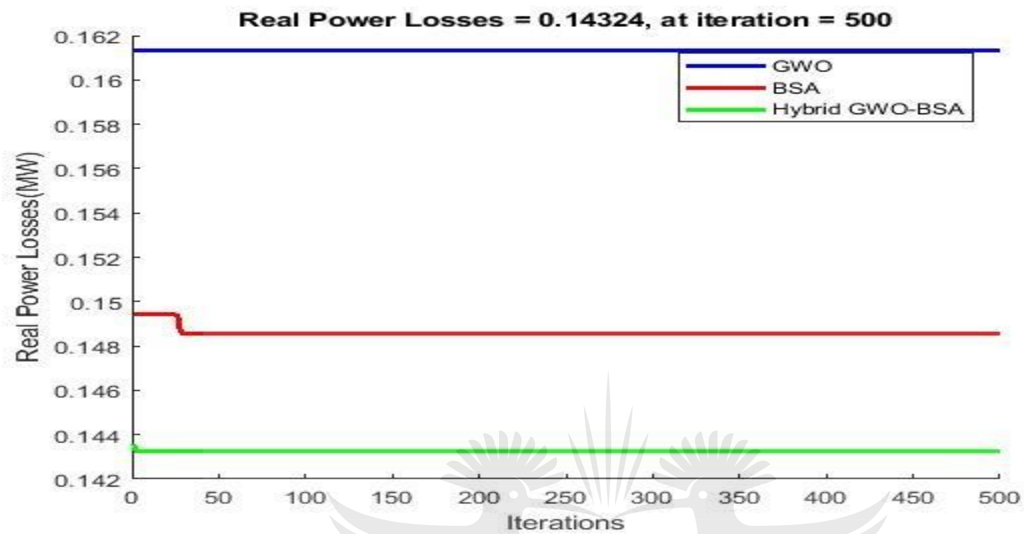


Fig 5.7: Real power loss minimization of the system under case study

5.5.4 Voltage stability improvement

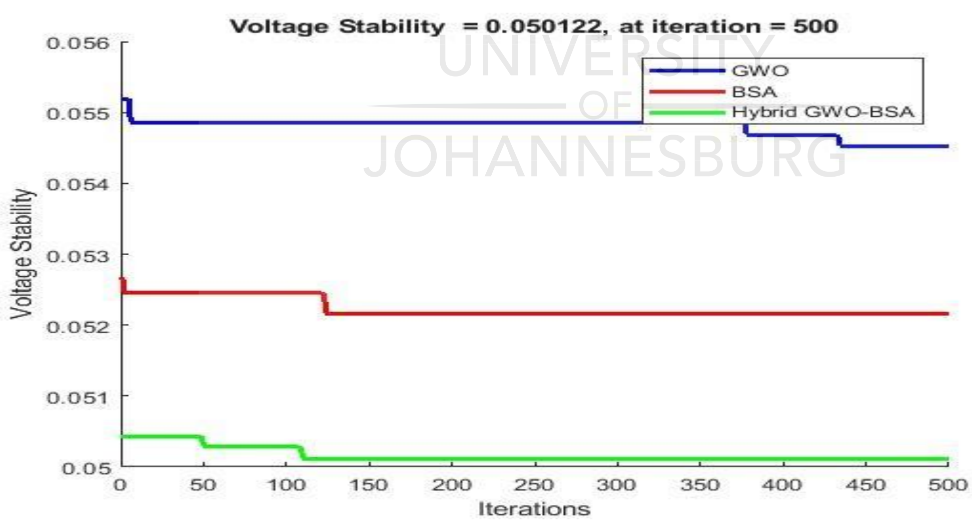


Fig 5.8: Voltage stability Improvement for the proposed system

5.5.5 Reactive power loss minimization

The reactive power loss minimization as part of the objective function can be seen in the

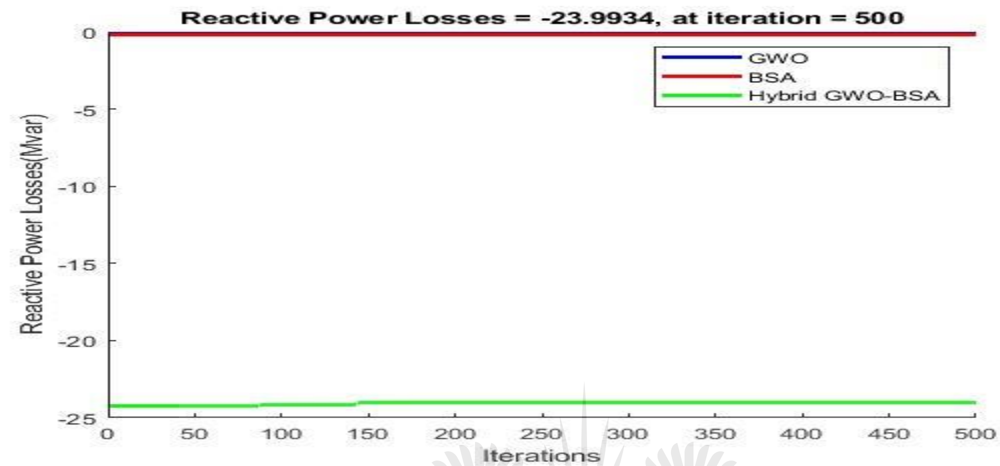


Figure 5.9: Reactive power losses of the system under study

5.5.6 Voltage deviation minimization

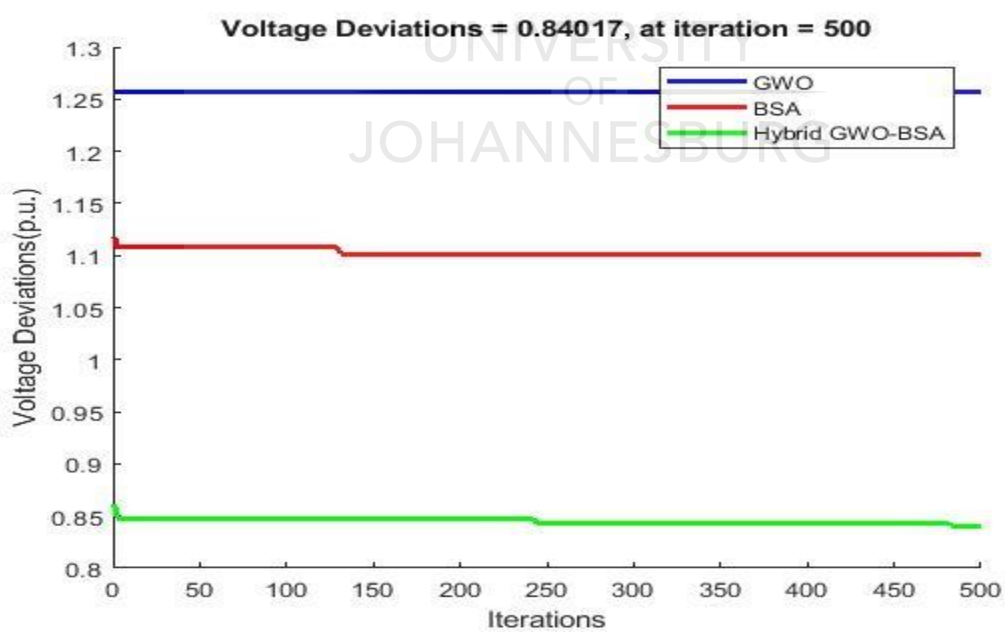


Fig 5.10: Voltage deviation improvement for the proposed system

Table 5.3: Shows Test results obtained by GWO-BSA & Hybrid GWO-BSA and objective value reduction by new approach

Case 1	GWO	BSA	Hybrid GWO-BSA
Fuel current cost ($/hr)	3.7×10^4	3.5×10^4	2.9×10^4
No of iteration	500	500	500
Case 2	GWO	BSA	Hybrid GWO-BSA
Minimization of reactive			
Power losses		0	-23.9934
No of iteration	500	500	500
Case 3	GWO	BSA	Hybrid GWO-BSA
Real power			
Losses minimization	0.16200	0.15000	0.14324
No of iteration	500	500	500
Case 4	GWO	BSA	Hybrid GWO-BSA
Voltage deviation			
Minimization	1.2670	1.1056	0.8407

No of iteration	500	500	500
Case 5	GWO	BSA	Hybrid GWO-BSA
Voltage stability	0.055321	0.05282	0.050122
No of iteration	500	500	500

The fuel cost, real power losses minimization, reactive power losses, voltage deviation as well as the voltage stability improvement in terms of objective goals are achieved in fig (5.6-5.10). It is observed from the figure (5.6-5.10) the hybrid optimization GWO-BSA gives better results as compared to the single algorithm.

5.6 CONCLUSIONS

In the present study, the authors have applied the hybrid GWO-BSA optimization algorithm for an effective optimal power flow with the inclusion of multi-facets devices to achieve the key objectives. It is observed that this algorithm is capable of achieving technical objectives. The proposed hybrid GWO-BSA algorithm was investigated on the IEEE-37 bus test system for different objective functions. From a practical point of view, the hybrid algorithm is more promising in achieving better results. This test system is equipped with STATCOM and UPFC devices at a price location, and from the result obtained, it is found that combination of GWO-BSA algorithm with the inclusion of FACTS devices effectively minimize the cost fuel, real losses, reactive power losses, voltage stability index and voltage stability in the power system.

The simulation results proved that the hybrid system is capable of solving optimal power problems with the inclusion of FACTS devices as compared with some results reported in the literature.

- Better results of the recommended (GWO-BSA) algorithm is achieved as compared to the ones reported in the literature.

- The real and reactive power losses associated with the system have significantly reduced to 0.14324 and -23.9934 at 500 iterations.
- The real fuel cost function was reduced from $3.8\times10^{4}\$/hr$ to $2.8\times10^{4}4/hr$ as part of the objective function.
- The voltage deviation index and voltage stability improvement have been achieved using a controlled factor as part of the key objective.

CHAPTER 6

A SECURE COMMUNICATION FOR IOT BASED SMART GRID UNDER MALICIOUS ATTACKS

6.1 INTRODUCTION

SG is one of the important technologies in the grid system for monitoring and controlling the data exchange among the consumers, energy producers, and peer system operators [1]. The management of demand and supply is effectively carried out by adopting the Information and Communication Technology (ICT) in SG [2]. The conventional grid has centralized one-way transmission from the generation plants to users and demand-driven response. The SG is the integration of the traditional grid, and the technologies of information and control. The modern SG provides the decentralized two-way transmission and efficiency driven response. SG delivers various features such as sustainability, efficiency, security and improved reliability [3] [4]. The SG contains two key components such as smart meter and service provider [5]. The smart meters frequently gather and transmits the various information like user's electricity consumption to control center for billing, timely monitoring and some analytical purposes [6]. The integration of IoT and SG provides various advantages such as connectivity, interoperability, etc [7]. SG uses smart digital technology to improve the reliability and efficiency of the system (Cano, 2018)

The features of ICT in SG contain the utilization of bidirectional communications technology, maximum utilization of software and hardware and extensive accessibility. Because of the extensive exposure of equipment and maximum transmissions among the equipment components, the SG is affected by the cyber-attacks [8]. In SG, the sensor data is generated over the wireless IoT devices (i.e., smart meter). Moreover, the IoT devices are exposed to logical and physical threat [9] [10]. The challenges faced in the SG communications are given as follows: In the utility, the real time imbalance among the energy consumption and generation over the data manipulation is occurred by attacker that generates damages and higher financial losses [11]. Since a greater number of homes are linked with SG. The effect of such attacks creates the significant loss or harm on society, e.g., varying the billing information of customer, varying the pricing information transferred to the customers and blackout [12]. Therefore, an effective security mechanism required in the IoT based SG to preserve the data from unauthorized users during data transmission. The major contributions of this research paper are given as follows:

- The integration of IoT into the SG helps to achieve an efficient, cost, reliable and sustainable data transmission during communication.
- Additionally, the IETS method is developed in the IoT based SG to secure the data transmission. The random number and certified parameter generated in the IETS is used to avoid the unauthorized users during communication.
- There are two different attacks are considered in the IoT based SG communications such as Man-in-the-Middle (MITM) Attack and black hole attack.

The organization of this research paper is given as follows: The literature survey about the recent techniques related to the security in IoT based SG is given in section 2. The security models considered in the proposed system is described in the section 3. The detailed description about the IETS used to improve the security in the IoT based SG is given in section 4. The performance and comparative results of the proposed system is detailed in section 5. Finally, the conclusion is made in section 6.

6.2 LITERATURE SURVEY

This section provides the literature review about the current researches related to the security in the IoT based SG.

Ahene, E., Qin, Z., Adusei, A.K. and Li, F [13] presented the data access control scheme for securing the access of Energy Service Provider (ESP) to customer data. Here, the customer is considered as a data owner and third-party stakeholder/ESP is considered as data user. The secure access to the data of customer is processed through the gateway device i.e., Energy Service Interface (ESI). The certificateless signcryption with proxy re-encryption (CLSPRE) scheme is developed to perverse the data. The delegation command from the data owner helps to encrypt the data for authorized data users. The plaintext information is does not obtained by the ESI. Therefore, the data is decrypted only by the authorized users as well as it verifies the data authentication and integrity.

Guan, Z., Li, J., Wu, L., Zhang, Y., Wu, J. and Du, X [14] developed the Ciphertext Policy Attribute Based Encryption (CP-ABE) based secure data acquisition method for the SG. Initially, the obtained data from the terminal are separated into blocks and then the separated blocks are encrypted along with its related sub-tree. Therefore, the encryption and transmission is simultaneously executed over the SG. Additionally, the threshold secret sharing method is used to secure the access tree data. This CP-ABE is eliminating the unwanted attributes in the communication.

Mahmood, K., Chaudhry, S.A., Naqvi, H., Shon, T. and Ahmad, H.F [15] presented the Diffie–Hellman based lightweight authentication scheme by using the RSA and AES. The RSA and AES are used to generate the session key in this IoT based SG. The hash-based message authentication is used for establishing the integrity of the message. The hybrid Diffie–Hellman scheme avoids the man-in-the-middle and replay attacks as well as it minimizes the computation and communication overheads.

U. B. Baloglu and Y. Demir [16] developed the lightweight data aggregation technique in smart metering architecture. At first, the data from the smart meters are received in terms of time series. Subsequently, the collected data is perturbed and it is encrypted by using a Decisional Diffie-Hellman (DDH) scheme. The developed DDH based SG to communicate with privacy preserving nodes and smart meters. In this smart metering, a privacy protection is required to secure the data transmission among the metering devices because the task scheduler is easily affected by the malicious users.

Chen, S., Wen, H., Wu, J., Lei, W., Hou, W., Liu, W., Xu, A. and Jiang, Y [17] presented the Edge Computing (EC) in the IoT based SG for addressing the problems related to low latency and high bandwidth. The edge computing applications are represented in three different scenarios such as advanced metering systems, power distribution and Micro-grid. Additionally, data privacy protection, data prediction, and task grading strategies are developed in this SG to enhance the privacy of the data transmission. The EC used in the IoT based SG has higher outage time during the data transmission. Besides, the current works mentioned, this research paper does not only focus on attacks. Consequently, in this regards, two types of attacks are considered while transmitting the data from which can be eliminated with proposed method during IOT based SG.

Authors in (Chiang, 1989), classified the stability of the system based on the energy increase at a particular time. The consistency between predicted measurements and the experimental measurements is used to locate and detect anomalous data with application of power flow contingency (Shi and Wang, 2018). Application of active power was analyzed based on physical parameters to guarantee safety of the data as proposed in (Uu, 1990). Nevertheless, the high computational overhead of these methods makes them inappropriate for real- time modelling classification (Fischl 1991). To reduce the effect of high computational time, a decision method was proposed by author in (He *et al.*, 2013). How delay attacks affect the stability of the power system proposed by authors (Rahimi, Parchure and Broadwater, no date; Wang, 2017). However, from the literature study carried out, authors did not consider effects of attacks during transmission and critical safety. Moreover, the existing works mentioned in this research are not focused mainly on attacks. So, in this research, two types of attacks are considered while transmitting the data from which can be eliminated with proposed method during IOT based SG.

6.3 Different attacks considered in the IoT based SG

The different security attack considered for the IoT based SG are MITM attack and black hole attack.

6.3.1 MITM Attack

The MITM attack defines that the man in the middle interrupts the data transmit by the transmitter and the data is transmitted after malicious tampering to the receiver. This MITM attack spreads the false data over the network and it causes severe consequences.

6.3.2 Black hole attack

The black hole attack is generally a denial of Service (DoS) attack that is one of the protuberant attacks. The black node is occurred during the route discovery phase. At first, the transmitter doesn’t know the route to the receiver. The black hole node comprises the transmitter like that is valid, fresh and optimal route to the receiver while the black hole node doesn’t have any route to receiver. In that case, the black hole node is present in the route of data transmission. After establishing the paths, the transmitter sends the packets to the black hole node and it starts to the drops the packet without transmitting to the destination node.

6.3 PROPOSED SYSTEM

The economic activity in a society is speed up by using a reliable power system. The traditional power system is ineffective when the amount of distributed renewable sources is connected with SG. This is because the consumers don't have any idea related to the power consumed by the loads. In order to overcome this, an IoT based SG is enabled to know the appropriate information from the SG. In SG, the smart meter is used as a transmitter for transmit the information from one place to another place. The information received from the smart meter are power consumption, RMS voltage, RMS current, apparent power demand and power factor of residential, industrial and commercial load. The data transmitted through the IoT is insecure to the various attacks due to the openness of the wireless channel. Therefore, an IETS method is developed in this IoT based SG to preserve the information during data transmission. The block diagram for proposed IETS integrated with IOT based SG is shown in below fig 6.1. The IoT-IETS has its own privacy and security due to low latency, computational cost, delay and communication overhead are the main concerns that leads to the study of the new proposed scheme.

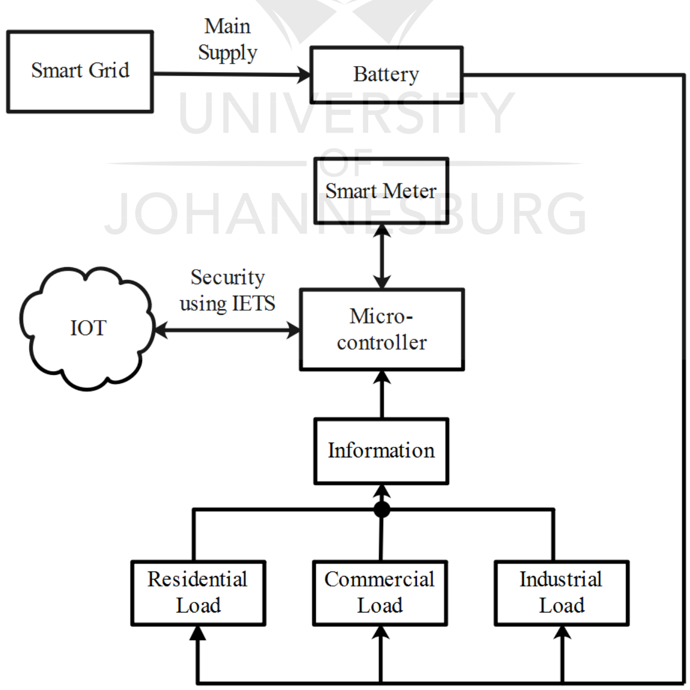


Fig 6.1 Block diagram of the IoT based SG using IETS

6.3.1. Smart meter

In this proposed system, the smart meter is an electricity meter which used to read and record the power consumption. The information monitored by the smart meter are power consumption, RMS voltage, RMS current, apparent power demand and power factor of residential, industrial and commercial load. It allows the data collection for remote monitoring interface known as Advanced Metering Infrastructure (AMI). The SM is generally a solid-state programmable device which executes a lot of functions such as remote turn-on or turn-off operations, net metering, power quality monitoring, time-based pricing, and bidirectional metering and measuring. The process of data encryption to encrypt the smart meter data is described in the following section.

6.3.2 Instant encrypted transmission-based security scheme

The security mechanism used in this proposed system has three different phases such as registration phase, detection phase, and implementation phase. The initial phase used in this encryption is registration phase. The private keys of sensors/ detectors of the network is generated based on the identity information by using the Key Generation Center (KGC). The detection phase is generally used as a sign and encryption phase. The transmitter (i.e., smart meter) are used to monitor the information from the SG. The responsible of the transmitter is to collect and encrypt the detected information. The third phase namely implementation phase receives the information through the IoT communication. Additionally, this phase decrypts the received information and also it allows only the authenticated node to access the information from the IoT communication. The aforesaid three phases are used for fast encrypted transmission and prevention under the IoT environment.

6.3.3 Registration phase

The process of each node is obtained the data from the KGC that is referred by the registration phase. The secret key K_{sec} for the IoT communication and the calculation of public key $K_{pub} = K_{sec}P$. The hash function $H_1$is used to create the parameter $r_n = H_1(ID_n)$ based on the identity information of the node n. The computation of r_n and private key K_{sec} is used to obtain the node n's private key.

6.3.4 Detection phase

In the detection phase, the information from the smart meters are collected and it encrypts the transmission data to the other nodes of the IoT. The operation of detection phase is explained as follows:

The random number y i.e., non-zero positive integer is selected by the transmitter and this phase computes the $Y = yP$. Then the w is calculated by the transmitter which is given in the equation (1).

$$w = e(P, P)^{yr_1} \tag{6.1}$$

where the random number selected by the transmitter is y and the parameter computed based on the transmitter's ID using KGC is represented as r_1.

The monitored data is compiled by the transmitter as file specified as n. The encryption process is expressed in the following equation (2).

$$N = n \oplus H_2(w) \tag{6.2}$$

where, N is the detection result that is encrypted data and it is achieved from the calculation of equation (6.2).

The certification parameter C_P is calculated in the detection phase that is given in equation (3).

$$C_P = \frac{r_2 u_1 Y}{u_1 + y} \tag{6.3}$$

where, the parameter calculated based on the receiver's identify using KGC is represented as r_2 and the transmitter's secret key created by the KGC is denoted as u_1. Moreover, the receiver receives three kinds of data such as parameter$Y$, certification parameter C_P and encrypted detection result N.

6.3.5 Implementation phase

The implementation phase receives the information from the IoT transmitters. The transmitting data of the node is first authenticated by the receiver. The assistance parameter M is calculated by the receiver that is given in equation (6.4).

$$M = \frac{r_1 K_{pub} + Y}{u_2} \tag{6.4}$$

where, the receiver's own private key is represented as u_2. The parameter w' is restored based on the calculation $w' = e(M, C_P)$. The message through the IoT communication is determined by using the equation (6.5).

$$n = N \oplus H_2(w') \tag{6.5}$$

6.4 Security against black hole and MITM attack

The attacker of MITM and black hole tries to interrupt the information (N, C_P, Y) passed through the IoT based SG. The information N requires to be decrypted when the attacker wants to access the information. However, the attacker doesn't have any chance to know the ransom number y that is created by transmitter in each transmission. The mitigation of attacks from the communication is not possible and it can break the information over the receiver. Furthermore, increasing the data volume in the smart grid system introduces data management and privacy considerations related to data collection with private information, and personal data leakage but, the attacker has no idea about the private key (u_2) of receiver.

The fake positive nonzero integer is generated by an attacker to interchange the random number (y) and C_P is generated again for tampering the information passed through the IoT. The generation of certification parameter (C_P) is ineffective due to less information about th e u_1. Therefore, both the MITM and black hole attack fails to access the information passed over the network.

Moreover, the attacker continuously receives the encrypted information cipher text and original text that is transmitted before the transmitter. But, the random number y is altered in each round by registration phase. Therefore, the attacker cannot interrupt the encrypted information from the previous plaintext and cipher text.

6.5 RESULTS AND DISCUSSION

The experimental results and comparative analysis of the proposed system are described in this section. The SG is developed and simulated in MATLAB R2018a that is operated in the Windows 8 operating system with Intel core i3 processor and 4GB RAM. The proposed IETS method is designed using Python script and implemented in Raspberry Pi. The information about the grid is collected in MATLAB and communicated with Raspberry pi for encryption and transferred to server node. In this proposed system, there are power consumption, RMS voltage, RMS current, apparent power demand, and power factor of loads are transferred through the IoT. The communication through the wireless channel is secured by developing the IETS with perfect public and private keys. The specification table for the proposed system is shown in below table 6.1.

Table 6.1. Specification table for Proposed Method

Channel type	Wireless Channel
Configuration option	Setting values
Interface queue length	5
Interface queue type	Omni antenna
Link layer type	LL
MAC layer protocol	MAC/802_15_4
Network interface type	WirelessPhy
Node Placement	Uniform Distribution
Number of sensor nodes	50
Propagation model	Propagation
Routing protocol	IETS
Simulation co-ordinates area	(100m, 100m)

6.5.1 Performance analysis

The performance of the proposed methodology is analyzed as power consumption for load, throughput, PDR and delay. Additionally, the performances of the proposed system is validated with the IoT based SG without IETS method. The IoT based SG without IETS is also simulated in the same MATLAB R2018a and Raspberry Pi.

6.5.2 Power consumption for load

The power consumption is defined as the amount of power consumed by the loads during peak hours. There are five different consumptions are analyzed as residential load, industrial load, commercial load, apparent power and load demand. We constructed and investigated a lightweight data scheme to be used in the performance analysis of the IoT based smart grid and other data were adapted from (Metering, Protection and Privacy-preserving, 2018), for comparison purpose.

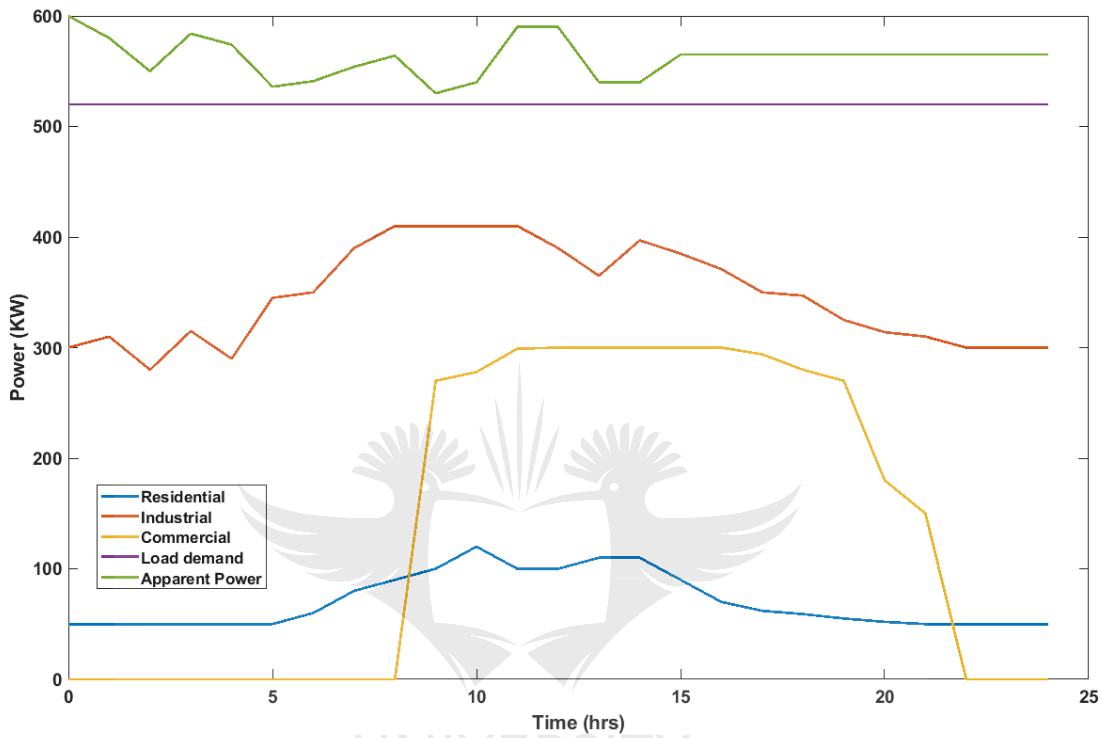


Fig 6.2 shows the power consumption for different loads which is processed in this IoT based SG.

Fig 6.2 shows the power consumption for residential load, industrial load, commercial load, apparent power and load demand. The power consumption between the proposed system and IoT without IETS are same, because it shows only the consumed power in SG. The power consumed by the residential, commercial and industrial are transmitted along with other parameters through the IoT. Then the transferred information is monitored by the end users in order to reduce the attacks.

6.5.3 Throughput

The throughput is defined as the number of packets successfully transmitted from the smart meter to the user. For an effectively designed network, the throughput is high even when the system is affected by the attackers.

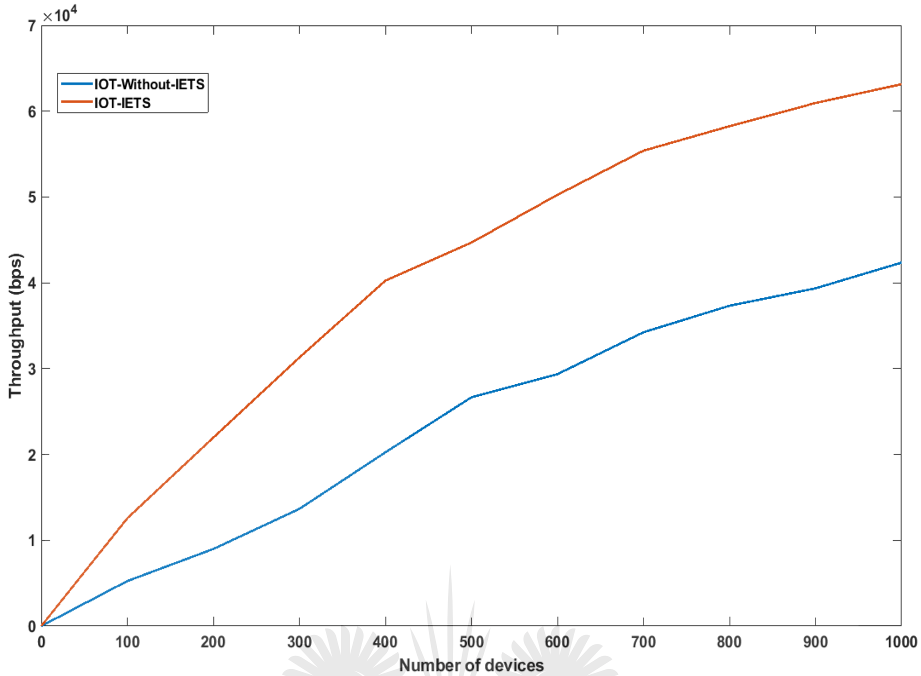


Fig 6.3. Analysis of Throughput

Fig 6.3 shows the comparison of throughput for proposed system and IoT without IETS. The throughput of the proposed system is high when compared to the IoT without IETS. The number of packets successfully transmitted to the receiver by proposed system is high, due to the validation of authorized users and attacks mitigation by IETS.

6.5.4 Packet delivery ratio

PDR is defined as the ratio between the amounts of packets received at the receiver to the number of packets transmitted by the sender.

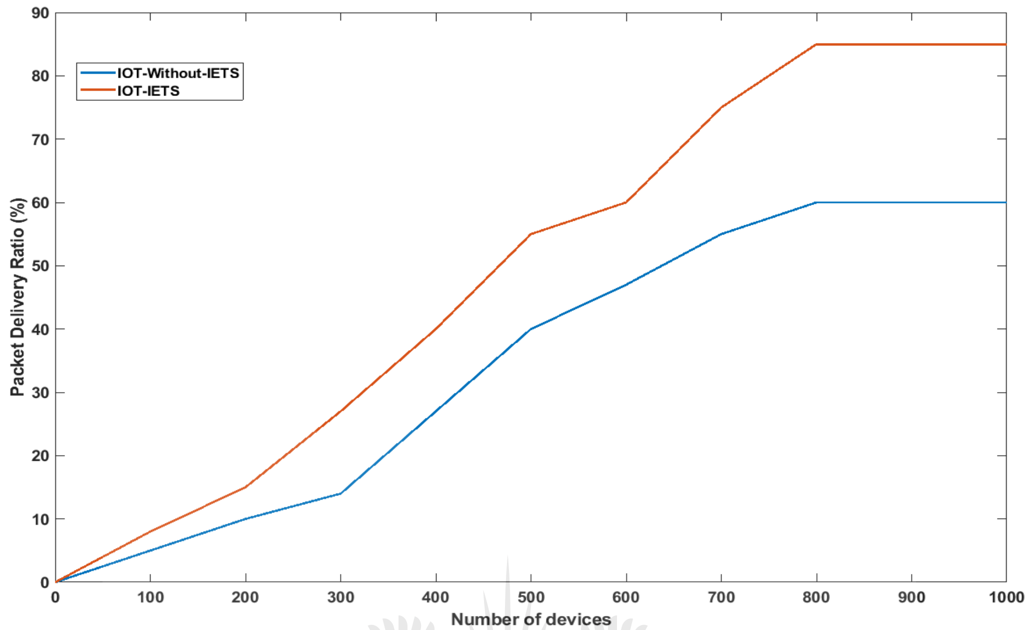


Fig 6. 4. Analysis of PDR

The comparison of PDR for proposed system with IoT without IETS is shown in the Fig 6.4. From the Fig 6.4, conclude that the PDR of the proposed system is high when compared to the IoT without IETS. The proposed system with high PDR shows that the SG communication using IETS losses only a smaller number of packets. The mitigation of black hole attacks helps to avoid the packet loss and also this IETS improves the confidentiality of the communication.

6.5.5 Delay

The amount of time taken to transmit the information from the transmitter to the receiver is defined as delay. The transferred information through the IoT based SG are power consumption, RMS voltage, RMS current, apparent power demand and power factor of different load.

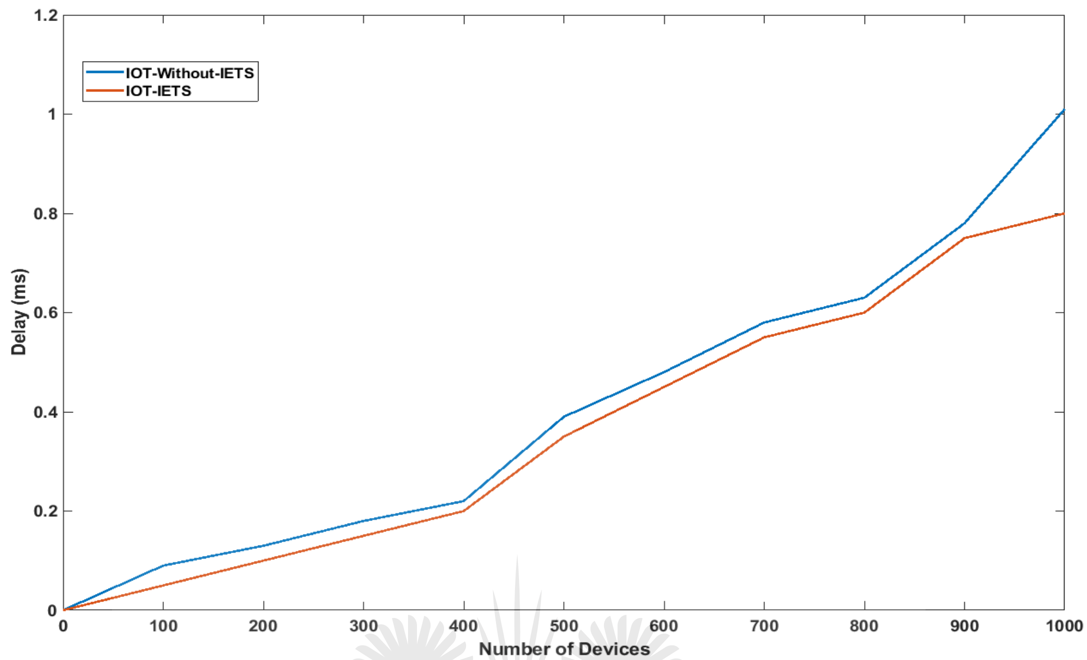


Fig 6.5. Analysis of Delay

Fig 6.5 shows the delay comparison for the proposed system and IoT without IETS. The delay of the proposed method is less when compared to the IoT without IETS. The reason for the higher delay of IoT without IETS is that the interception of black hole and MITM attacks during data transmission. We simulate a large number of nodes in order to reduce the attacks, however the delay increases when more attacks are received.

6.5.6 Comparative analysis

The performance of proposed system is compared with EC-IoT [17] in terms of delay to know the efficiency of the proposed system. The edge computing application is developed in three different scenarios such as power distribution, Micro-grid, advanced metering systems. Additionally, the secure access of different terminals is developed by using edge computing.

Table 6.2. Comparative analysis of proposed system and EC-IoT

Number of devices	**Delay (ms)**	
	EC-IoT [17]	**Proposed system**
100	0.1	0.05
200	0.15	0.1
300	0.25	0.15
400	0.3	0.20
500	0.45	0.35
600	0.5	0.45
700	0.6	0.55
800	0.8	0.60
900	0.9	0.75
1000	1.0	0.8

Table 1 shows the comparative analysis of the delay for EC-IoT [17] and proposed system. From the Table 6. 2, conclude that the proposed method has less delay when compared to the EC-IoT [17]. The proposed system with less delay is obtained based on the faster data encryption achieved by the IETS method. Moreover, the IETS mitigates the black hole and MITM attacks during data transmission that helps to reduce the delay. However, the EC-IoT [17] has high delay than the proposed system due to the higher outage time of the edge computing.

6.6 Conclusion

In this paper, the IETS method is developed to secure the communication through the IoT. The communication of IoT based SG is analyzed under two different attacks such as black hole and MITM attack. The smart meter presents the in SG collects and transmits the five different information such as power consumption, RMS voltage, RMS current, apparent power demand and power factor of different load. The IETS used in the proposed system authenticates the user as well as it mitigates the attacks based on the generated random number, certified parameter, public key and private key. The performance analysis shows that the proposed system achieves better performance than the IoT without IETS. Moreover, the delay of proposed system is less than the EC-IoT. For example, the delay of the proposed system for 500 devices is 0.35ms, it is less when compared to the EC-IoT.

Conclusion and Future work

7.1 Conclusion

The growing demand for electricity and the need for more efficient and environmentally sustainable generation of electricity have resulted in development of DG units. Several technologies, and their adverse installation into electrical power system affected the distribution network configuration. All the above resulted in reconsideration and change in: the viewpoint, the old-style configuration and the operation of the networks (e.g., bidirectional power flow in contrast to the unidirectional power flow from higher to lower voltage levels) important in turn to possibly substantial trials in terms of control, security and protection of the entire electric power system and particularly of distribution networks. Furthermore, all the above new facts united with continual adjustments of distribution networks brought about a series of other significant problems that must be addressed and further studied in order consumers to endure to be well provisioned with continuous power supply of high quality and at minimum cost. The present contribution of the thesis is conducted wide-reaching directing for more efficient and secure electric power systems, focusing on electricity distribution networks with specific references to distributed generation. All concluded the impact of DG on boosting voltage profiles, power losses and cost saving in distribution networks is analyzed, the decision problem of the optimum size and placement of new DGs in existing distribution networks is studied.

In line with the first objective of this work, a mathematical model of the scheme was developed with both single and multi-objective hybrid optimization with technical objective of decreasing power loss, boosting voltage profile and cost saving in the distribution system. The model was made simple, and is tested on IEEE 33 and 69 standard system and simulation results from the model gives a better result in terms of power loss and voltage stability by installing the DG at 13^{th} ,10^{th} and 30^{th} bus.

As regards to the size of the renewable energy sources based on DG, as in line with the second objective, a mathematical model based on Water, Energy and Food Algorithm was developed to handle the uncertainties produced during the course of handling this renewable energy source. The results were generated using Mat power and Matlab, energy utilization of the DG in the distribution system was achieved.

The third objective of the thesis, investigate the use of multi-facts devices (Static synchronous compensator (STATCOM) and unified power flow controller (UPFC) for injection of system's power flow to elevate the power flow in terms of various objectives such as fuel cost, minimization of real power losses, reactive power losses, voltage stability and voltage stability index. An effective hybridized Grey wolf optimization and Backtracking search optimization (GWO-BSA) is implemented with FACTS devices for obtaining the best for multi-constrained problem for optimal power flow and the result obtained indicates an effective performance of the proposed algorithm in solving the objective function.

Lastly, a secure communication for IOT based smart grid is developed to prevent attacks from the data transmitted from the smart grid to the user was studied in Chapter 6. Instant Encrypted Transmission system (IETS) is developed to reduce the risk of data transmitted from the smart grid to the user. Smart meter is employed in the smart grid to assist in transmitting various parameters such as (power consumption, RMS current, RMS voltage, apparent power and power factor) for residential, commercial and industrial loads. IETS algorithm is successful in lowering power consumption of various loads, packet delivery ratio and delay time for 1000 devices at 0.8ms in comparison with the existing methods in literature.

The research works presented in the thesis cover optimization problems for optimal allocation and sizing of the distributed generation in distribution system. Models developed are reliable in minimizing power losses, voltage stability index, voltage profile as well as cost of this renewable energy sources are minimized which are the key objective of the research. Brief overview of future work is presented herein.

CHAPTER 7

7.2 FUTURE WORK DIRECTION

This research work may be extended for future study in the following:

- The study of the impact of several network types containing transmission and distribution lines, as well as the study of the impact of different types (e.g., DGs that inject both real and reactive power) and sizes of DG in the improvement of voltage profiles and limitation of real and reactive power losses by application of Artificial intelligence. Furthermore, the implementation of the developed decision-making algorithm for the optimum size and placement of DG units in several distribution networks in order to evaluate its performance and effectiveness. Finally, the decision-making algorithm could be further developed in order to be capable to allocate instantaneously two or even more DG units of different type and size and even be combined with an existing optimization algorithm and/or with a load flow estimation methodology.
- Sensitivity analysis adopted in literature for the investigation of the performance of lightening in the distribution system with DG coupled can be re-examined by considering different loads, lightening and insulation levels. A code program should generate the

waveforms results to assist network planners and power utilities engineers in providing protection for modern power distribution networks.

- This model can be further developed to accommodate load shedding and wind curtailment. Wind power considered in this model are assumed constant voltage and no voltage control equipment consideration, therefore there is need to re-designed the codes to accommodate curtailment and down regulate the wind power cost.
- The models can be extended to analyze the effect of regulation of distribution system operation networks planning. It will investigate the economic incentives prosperity of various distribution system operation network. Optimal setting to accommodate the DG will impact positively in boosting the voltage profiles and reduction in losses.

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APPENDIX A: Evidences of Journal publications published

(PAPER 1)

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ELECTRICAL & ELECTRONIC ENGINEERING | RESEARCH ARTICLE

Optimization techniques applied for optimal planning and integration of renewable energy sources based on distributed generation: Recent trends

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Abstract: Numerous potential advantages to the requirements and effectiveness of the supplied electricity can be accomplished by the installation of distributed generation units. In order to take full advantage of these benefits, it is essential to position the Distributed Generation (DG) units in appropriate locations. Otherwise, their installation may have an adverse effect on the quality of energy and system operation. Several optimization techniques have been created over the years to optimize distributed generation integration. Optimization techniques are therefore constantly changing and have been the main attention of many fresh types of research lately. This article evaluates cutting-edge techniques of optimizing the issue of positioning and sizing distributed generation units from renewable energy sources based on recent papers that have already been applied to distribution

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PUBLIC INTEREST STATEMENT

Several optimization techniques have been created over the years to optimize the integration of distributed generation. Optimization techniques are therefore constantly changing and have been the main attention of many fresh types of research lately. This article evaluates cutting-edge techniques of optimizing the issue of positioning and sizing distributed generation units from renewable energy sources based on recent papers that have already been applied to the distribution system. Furthermore, this article pointed out the environmental, economic, technological and regulatory drivers that lead to a rapid interest in the DG system based on renewable sources. According to the investigation carried out, the area of artificial intelligence techniques is still receiving attention than conventional optimization techniques for optimal DG planning in a power distribution network system from different point of view. Computational techniques in hybrid optimization techniques convergence take place faster than the conventional optimization techniques.

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Research paper

Multi-objective for optimal placement and sizing DG units in reducing loss of power and enhancing voltage profile using BPSO-SLFA

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ABSTRACT

Algorithms are used to optimize both single and multi-objective system limits. This research aimed to detect the optimal location and size of the DGs, which can significantly minimize power loss and improve the stability of the voltage. The research uses binary particle swarm optimization and shuffled frog leap (BPSO-SLFA) algorithms for simulation and testing of an optimal power flow (OPF) on 33 and 69 bus radial distribution system. The result shows that the algorithms give better DG allocation and minimizes the power losses but at the nascent stage of advancement. The power losses associated with the system have significantly reduced up to 31.8244kW using multi-DGs reconfiguration placement. The outcomes are established to verify the potency of the recommend algorithm to minimize losses, general improvement in voltage profiles and cost saving for various distribution system. However, the proposed methodology can be used as a reliable method in DG settings and sizing in distribution network system which produce better outputs rather than hybrid grey wolf optimization (GWO) and hybrid big bang big crunch.

1. Introduction

The Institute of Electrical Electronics Engineering (IEEE) gives a concise definition of distributed generation as a power generation that is adequate compact than central generating plants and are connected closer to the distribution system (Chiradeja and Ramakumar, 2004; Pepermans et al., 2005; Singh and Parida, 2015). The rapid development in technology, global concern about the environment and the demand of the customers for cheap and consistent electric power have led to an increasing interest in DG (Kansal et al., 2016). However, optimal allocation and sizing of DG may bring various advantages such as voltage control through cost (El-Khattam et al., 2004), boosting reliability (Rohatgi et al., 2006), harmonic reduction (Tagore and Gupta, 2017), minimization of real and reactive losses (Mallipeddi et al., 2017), voltage stability and network loss reduction (Esmaili et al., 2014), and infeasible network configuration (Nguyen et al., 2016).

Many optimization algorithm and techniques have been developed for the application of energy technologies problem. Among the various techniques, algorithms and optimization present the highest potential for use in the placement of DG. Nguyen et al. (2016) adopted the novel cuckoo based (CSA) algorithm for placement of DG with the technical objective of minimizing the active power loss and improving the strength of the voltage. Yahiaoui et al. (2017) proposed GWO for the optimal sizing of hybrid renewable systems to lessen the cost of hybrid power generation. Other researchers have proposed a hybridization algorithm in order to replace the traditional algorithm. A particle artificial bee colony (PABC)-hybrid harmony search algorithm (HSA) approach was developed to optimal size and location of the DG in distribution system (Muthukumar and Jayalalitha, 2016). Their results showed that the efficiency of the proposed hybrid algorithm in obtaining optimal solution for simultaneous placement of DGs and shunt capacitors in distribution networks. Kefayat et al. (2015) applied artificial bee colony and hybrid ant colony optimization to the distribution system in order to control emissions expelled by the substation and overall improvement of the voltage stability. Doagou-mojarrad et al. (2013) reported a fuzzy based intelligent system based on shuffled frog leap algorithm to resolve optimal allocation problem with the aim of minimizing power loss, energy cost and control of emission produced. Results showed that the simulation illustrate the good performance and applicability of the proposed method. Another research conducted by Moradi and Abedini (2012), which obtained a better result in terms of reduction of loss of power, boosting voltage regulation, and maintaining voltage stability by application of particle swarm algorithm and genetic algorithm. Selim et al. (2019), proposed chaotic sine cosine algorithm for optimal location and sizing DG in distribution network with minimum

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APPENDIX B IEEE-69 Test

```
clc
tic
addpath('matpower6.0')
```

```
%(INITIALIZING SWARM PARAMETER)
n=20;
dim=5;% Dimmension of searching space
x=load('swarm69.m');% Creating a swarm
vnew=rand(n,dim);% Creating a randomized initial velocity
vold=vnew;
sig=zeros(n,dim);
pbest=load('swarm69.m');% Creating pbest matrice
gbest=[4 3 14 23 19];% Introducing a randomized gbest
fitness=zeros(1,n);
wmax=0.9;
wmin=0.4;
r1=rand(n,dim);% Creating a randomized matrice, size (n x dim)
r2=rand(n,dim);% Creating a randomized matrice, size (n x dim)
iter=0;
maxiter=5;% Maximum iteration
tap=[11 12 13 14 43 44 45 71 0 0 0 0 0 0 0 0
    4 5 6 7 8 46 47 48 49 52 53 54 55 56 57 58
    3 9 10 35 36 37 38 39 40 41 42 69 0 0 0 0
    21 22 23 24 25 26 59 60 61 62 63 64 73 0 0 0
    15 16 17 18 19 20 70 0 0 0 0 0 0 0 0 0];
ta=tap';
caselv=loadcase(case69);
% Establish the incidence matrix
doc=xlsread('branch69');
nhanh=73;
nut=69;
matrix=zeros(nhanh,nut);
    nutdau=doc(:,1);
    nutcuoi=doc(:,2);
for i=1:nhanh
matrix(i,nutdau(i))=1;
matrix(i,nutcuoi(i))=1;
end

 % Initializing fitness function for pbest
 fpbest=zeros(1,n);
 for i=1:n
     fpbest(i)=50000;
 end

% Main loops
while iter<maxiter
    iter=iter+1;
    w=wmax-(wmax-wmin)*iter/maxiter;% Specilize the weight coefficient
    c1=2*rand(1);
```

```
c2=2*rand(1);
% Updating velocity
for i=1:n
    for j=1:dim
        vold=vnew;
    vnew(i,j)=w*vnew(i,j)+c1*r1(i,j)*(pbest(i,j)-x(i,j))+c2*r2(i,j)*(gbest(j)-x(i,j));
   if abs(vnew(i,j))==abs(vold(i,j))
       vnew(i,j)=rand(1,1).*vnew(i,j);
   end
    end
end
% Updating sigmoid function
for i=1:n
    for k=1:dim
    sig(i,k)=length(nonzeros(ta(:,k)))/(1+exp(-vnew(i,k)));
    end
end
% Updating particles' coordinate
for i=1:n
    for k=1:dim
        x(i,k)=ta(ceil(sig(i,k)),k);
    end
end
% Calculating fitness function for each particle
     for k=1:n
        hop=caselv ; matran=matrix;
         for i=1:dim
             hop.branch(x(k,i),11)=0;
             matran(x(k,i),:)=0;
         end
 % Check on constraint of radial distribution network
         for j=1:length(matrix(1,:))
             for i=1:length(matrix(1,:))
                 if sum(matran(:,i))==1
                     row=find(matran(:,i));
                     matran(row,:)=0;
                 end
             end
         end
         if sum(sum(matran))==0
             result=runpf(hop);
             fitness(k)=sum(result.branch(:,14)+result.branch(:,16))*1e3;
         end
     end
% Updating pbest
      for k=1:n
```

```
          if fitness(k)<fpbest(k)
              pbest(k,:)=x(k,:);
              fpbest(k)=fitness(k);
          end
        end
    % Calculating value of gbest
        hop1=caselv;
        for i=1:dim
           hop1.branch(gbest(i),11)=0;
        end
        result=runpf(hop1);
        fgbest=sum(result.branch(:,14)+result.branch(:,16))*1e3;
        gbestvolt=result.bus(:,8);
        minvolt=min(gbestvolt);
   % Updating gbest
    for k=1:n
       if fpbest(k)<fgbest
          gbest=pbest(k,:);
       end
    end
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% SFLA
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
popsize= 20;  %size of frogs
npar = 1; % Dimension of the problem;number of parameters=1
maxit = 2; % Maximum number of iterations
nbb=69; %number of buses
DG_real_min=0; DG_real_max=100;  %cap size min and max values in pu
bus_min=1;bus_max=69;
bmva=100;
bkv=12.66;
DGSIZE=zeros(popsize);
ndevices=1;
NDG=ndevices;

pf=0.9;
ang= acosd(pf);
pf1=sind(ang);


bdata=[1 0.0 0.0
2 0.0 0.0
3 0.0 0.0
4 0.0 0.0
5 0.0 0.0
6 2.60 2.20
```

7 40.40 30.00
8 75.00 54.00
9 30.00 22.00
10 28.00 19.00
11 145.00 104.00
12 145.00 104.00
13 8.00 5.50
14 8.00 5.50
15 0.0 0.0
16 45.50 30
17 60.00 35.00
18 60.00 35.00
19 0.0 0.0
20 1.00 0.60
21 114.00 81.00
22 5.30 3.50
23 0.0 0.0
24 28.00 20.0
25 0.0 0.0
26 14.0 10.0
27 14.0 10.0
28 26.0 18.6
29 26.0 18.6
30 0.0 0.0
31 0.0 0.0
32 0.0 0.0
33 14.0 10.0
34 19.50 14.00
35 6.00 4.00
36 26.0 18.55
37 26.0 18.55
38 0.0 0.0
39 24.0 17.00
40 24.0 17.00
41 1.20 1.0
42 0.0 0.0
43 6.0 4.30
44 0.0 0.0
45 39.22 26.30
46 39.22 26.30
47 0.00 0.0
48 79.00 56.40
49 384.70 274.50
50 384.70 274.50
51 40.50 28.30
52 3.60 2.70

```
53 4.35 3.50
54 26.40 19.00
55 24.00 17.20
56 0.0 0.0
57 0.0 0.0
58 0.0 0.0
59 100.0 72.0
60 0.0 0.0
61 1244.0 888.00
62 32.0 23.00
63 0.0 0.0
64 227.0 162.00
65 59.0 42.0
66 18.0 13.0
67 18.0 13.0
68 28.0 20.0
69 28.0 20.0
];
ldata=[
1 1 2 0.0005 0.0012
2 2 3 0.0005 0.0012
3 3 4 0.0015 0.0036
4 4 5 0.0251 0.0294
5 5 6 0.3660 0.1864
6 6 7 0.3811 0.1941
7 7 8 0.0922 0.0470
8 8 9 0.0493 0.0251
9 9 10 0.8190 0.2707
10 10 11 0.1872 0.0691
11 11 12 0.7114 0.2351
12 12 13 1.0300 0.3400
13 13 14 1.0440 0.3450
14 14 15 1.0580 0.3496
15 15 16 0.1966 0.0650
16 16 17 0.3744 0.1238
17 17 18 0.0047 0.0016
18 18 19 0.3276 0.1083
19 19 20 0.2106 0.0696
20 20 21 0.3416 0.1129
21 21 22 0.0140 0.0046
22 22 23 0.1591 0.0526
23 23 24 0.3463 0.1145
24 24 25 0.7488 0.2745
25 25 26 0.3089 0.1021
26 26 27 0.1732 0.0572
27 3 28 0.0044 0.0108
```

```
28 28 29 0.0640 0.1565
29 29 30 0.3978 0.1315
30 30 31 0.0702 0.0232
31 31 32 0.3510 0.1160
32 32 33 0.8390 0.2816
33 33 34 1.7080 0.5646
34 34 35 1.4740 0.4673
35 3 36 0.0044 0.0108
36 36 37 0.0640 0.1565
37 37 38 0.1053 0.1230
38 38 39 0.0304 0.0355
39 39 40 0.0018 0.0021
40 40 41 0.7283 0.8509
41 41 42 0.31 0.3623
42 42 43 0.0410 0.0478
43 43 44 0.0092 0.0116
44 44 45 0.1089 0.1373
45 45 46 0.0009 0.0012
46 4 47 0.0034 0.0084
47 47 48 0.0851 0.2083
48 48 49 0.2898 0.7091
49 49 50 0.0822 0.2011
50 8 51 0.0928 0.0473
51 51 52 0.3319 0.1114
52 9 53 0.1740 0.0886
53 53 54 0.2030 0.1034
54 54 55 0.2842 0.1447
55 55 56 0.2813 0.1433
56 56 57 1.5900 0.5337
57 57 58 0.7837 0.2630
58 58 59 0.3042 0.1006
59 59 60 0.3861 0.1172
60 60 61 0.5075 0.2585
61 61 62 0.0974 0.0496
62 62 63 0.1450 0.0738
63 63 64 0.7105 0.3619
64 64 65 1.0410 0.5302
65 11 66 0.2012 0.0611
66 66 67 0.0047 0.0014
67 12 68 0.7394 0.2444
68 68 69 0.0047 0.0016
];


%obtaing all required values from branch and line data
```

```
bpl=zeros(nbb,1);
bql=zeros(nbb,1);
pl=bdata(:,2);
ql=bdata(:,3);
se=ldata(:,2);
re=ldata(:,3);
r=ldata(:,4)*bmva/(bkv*bkv);
x=ldata(:,5)*bmva/(bkv*bkv);
rand('seed',10)

bpl=( pl/bmva )*(1/1000); % In MW p.u
bql=(ql/bmva )*(1/1000); % In MVAR p.u

count=0;
% sending changed values as input argument to subfunction
[tploss,tqloss,vm,busno,totalLoss]=lf(bpl,bql,se,re,r,x,nbb,bmva,bkv);
voltagebefore = vm;
plossbefore = tploss;
qlossbefore = tqloss;
% now we obtain the buslocation and from now there is no need of
% calculating VSI again;incrementing count to 1
count=1;

% Initializing swarm and velocities
par=rand(popsize,NDG); % random population of continuous values
v = rand(popsize,NDG); % random velocities

% Evaluate initial population
%Generating random values for cap sizes within the limits
for m=1:popsize
  for n=1:NDG
   par(m,n)=( DG_real_min + ((DG_real_max-DG_real_min) * rand ));
  end
end

%Considering the intial parameter values as cap sizes and intial losses
DGSIZE= par;
bplbefore=bpl;

for iter=1:popsize    % converting cap size into p.u
  for n=1:NDG
     DGSIZE(iter,n)= ( DGSIZE(iter,n)/bmva )* (1/1000) ;
     end
end

%bus is the location of the bus where cap is to be installed
```

```
 %busposition is the location of the bus where cap is to be installed
 voltage = vm;
 bqlbefore=bql;
lossFunction(1) = tploss;
for k = 1:nbb
  bpl(k,1)=0;
  bql(k,1)=0;
 [tploss1,tqloss,vm,busno,totalLoss]=lf(bpl,bql,se,re,r,x,nbb,bmva,bkv);
   lossFunc(k)= tploss - tploss1;
   bpl(k,1)=bplbefore(k,1);
   bql(k,1)=bqlbefore(k,1);

end
minloss=min(lossFunc)
maxloss= max(lossFunc)

for m=1:nbb
pli(m)= (lossFunc(m)-minloss)/(maxloss - minloss);
input(m,1)=pli(m)
input(m,2)=voltage(m)
end
fis=readfis('fuzzy')
out=evalfis(input,fis)

for nn=1:nbb
    output(nn,1)=nn;
    output(nn,2)=out(nn);
end
[buspos suitabilityindex] =  sortrows(output,-2)
for nn=1:ndevices
    busposition(nn)= buspos(nn,1)
end
bus=busposition;


for i=1:popsize
    %As DG injects real power,real power loss is reduced by subracting
    %capsize from the loss
    for k=1:NDG
    bpl(bus(k),1)=bpl(bus(k),1)-DGSIZE(i,k)*pf;
    bql(bus(k),1)=bql(bus(k),1)-DGSIZE(i,k)*pf1;
    end
    % sending changed values as input argument to subfunction
   [tploss,tqloss,vm,busno,totalLoss]=lf(bpl,bql,se,re,r,x,nbb,bmva,bkv);
    %Obtaining the fitness function by placing cap
```

```
    lossfunct(i,2:ndevices+1)=DGSIZE(i,:);
    lossfunct(i,1)=tploss;
    %as we are adding a single cap,the old cap size that is added above has
    %to be eliminated
    for k=1:NDG
    bpl(bus(k),1)=bpl(bus(k),1)+DGSIZE(i,k)*pf;
    bql(bus(k),1)=bql(bus(k),1)+DGSIZE(i,k)*pf1;
    end
end
difference=1;
iter=0;
w_in = 0.35;
w_f = 1.9;
%for m=1:100
%Obtaining the entire fitness function by placing different sizes of cap
 while difference >= 0.0000001
     iter=iter+1;
F=lossfunct;
F1=sortrows(F,1);
 c = w_f - ((w_f - w_in)*iter/maxit);
    nmemplexes=20;
k=1;

for i=1:round(popsize/nmemplexes)
    temp=0;
    for j=1:nmemplexes
   memplex(i,temp+1:ndevices+temp)= F1(k,2:ndevices+1);
   memplexloss(i,j)= F1(k,1);
   k=k+1;
   temp=temp+ndevices;
       if k == popsize+1
        break
       end
    end
end

vv=0;
%Obtaining the entire fitness function by placing different sizes of cap
temp1=0;
    gbestfrogsize=0;
    gbestfrogloss=0;
    bestfrogloss=0;
    worstfrogloss=0;

for i=1:nmemplexes
     for zz=1:2
```

```
 gbestfrogsize=memplex(1,1:ndevices);
 gbestfrogloss=memplexloss(1,1);
 bestfrogsize(i,:)=memplex(1,temp1+1:ndevices+temp1);
 bestfrogloss(i)=memplexloss(1,i);
 v=length(memplex(:,i));
 worstfrogsize(i,:)=memplex(v,temp1+1:ndevices+temp1);
 worstfrogloss(i)=memplexloss(v,i);
 changeinfrogposition(i,:) = c*rand()*(bestfrogsize(i,:)-worstfrogsize(i,:));
 newworstfrogsize(i,:) = worstfrogsize(i,:)+changeinfrogposition(i,:);

for g=1:ndevices
 if newworstfrogsize(i,g) > DG_real_max
            newworstfrogsize(i,g) = DG_real_max;
        end
        if newworstfrogsize(i,g) < DG_real_min
            newworstfrogsize(i,g) = DG_real_min;
        end
end

 for k=1:NDG
 bpl(bus(k),1)=bpl(bus(k),1)-newworstfrogsize(i,k)*pf;
 bql(bus(k),1)=bql(bus(k),1)-newworstfrogsize(i,k)*pf1;
 end

 % sending changed values as input argument to subfunction
[tploss,tqloss,vm,busno,totalLoss]=lf(bpl,bql,se,re,r,x,nbb,bmva,bkv);
 loss=tploss;
for k=1:NDG
   bpl(bus(k),1)=bpl(bus(k),1)+newworstfrogsize(i,k)*pf;
 bql(bus(k),1)=bql(bus(k),1)+newworstfrogsize(i,k)*pf1;
end

  if loss < worstfrogloss(i)
      memplex(v,temp1+1:ndevices+temp1) = newworstfrogsize(i,:);
      worstfrogloss(i)=loss;
  else
      changeinfrogposition(i,:) = c*rand()*(gbestfrogsize-worstfrogsize(i,:));
      newworstfrogsize(i,:) = worstfrogsize(i,:)+changeinfrogposition(i,:);

           for g=1:ndevices
             if newworstfrogsize(i,g) > DG_real_max
            newworstfrogsize(i,g) = DG_real_max;
        end
        if newworstfrogsize(i,g) < DG_real_min
            newworstfrogsize(i,g) = DG_real_min;
        end
```

```
end
           for k=1:NDG
 bpl(bus(k),1)=bpl(bus(k),1)-newworstfrogsize(i,k)*pf;
 bql(bus(k),1)=bql(bus(k),1)-newworstfrogsize(i,k)*pf1;
 end

 % sending changed values as input argument to subfunction
[tploss,tqloss,vm,busno,totalLoss]=lf(bpl,bql,se,re,r,x,nbb,bmva,bkv);
 loss=tploss;
for k=1:NDG
bpl(bus(k),1)=bpl(bus(k),1)+newworstfrogsize(i,k)*pf;
bql(bus(k),1)=bql(bus(k),1)+newworstfrogsize(i,k)*pf1;
end

  if loss < worstfrogloss(i)
      memplex(v,temp1+1:ndevices+temp1) = newworstfrogsize(i,:);
      worstfrogloss(i)=loss;
  else
                memplex(v,temp1+1:ndevices+temp1) =rand(1,ndevices)/bmva ;
      end
  end
  tloss=0;
  for t=1:length(memplex(:,temp1+1))
        for k=1:NDG
         bpl(bus(k),1)=bpl(bus(k),1)-memplex(t,k+temp1)*pf;
         bql(bus(k),1)=bql(bus(k),1)-memplex(t,k+temp1)*pf1;
         end
         % sending changed values as input argument to subfunction
        [tploss,tqloss,vm,busno,totalLoss]=lf(bpl,bql,se,re,r,x,nbb,bmva,bkv)
         voltageafter=vm;
         tloss(t,1)=tploss;
        for k=1:NDG
        bpl(bus(k),1)=bpl(bus(k),1)+memplex(t,k+temp1)*pf;
        bql(bus(k),1)=bql(bus(k),1)+memplex(t,k+temp1)*pf1;
          tloss(t,k+1)=memplex(t,k+temp1);
         end
  end
  loss1=sortrows(tloss,1);
  memplex(:,temp1+1:ndevices+temp1)= loss1(:,2:ndevices+1);
memplexloss(:,i)= loss1(:,1);
for zz=1:length(memplex(:,temp1+1))
    vv=vv+1;
lossarray(vv,2:ndevices+1)=memplex(zz,temp1+1:ndevices+temp1);
lossarray(vv,1)=memplexloss(zz,i);
end
```

```
     end
    temp1=temp1+ndevices;
end
lossfunct=lossarray;
    fit_store(iter) = gbestfrogloss;
    avg_fitness(iter) =mean(lossarray(:,1));
    difference =  avg_fitness -  fit_store
end
gbestfrogsize=memplex(1,1:ndevices)
gbestfrogloss=memplexloss(1,1);

     for k=1:NDG
    bpl(bus(k),1)=bpl(bus(k),1)-gbestfrogsize(1,k)*pf;
    bql(bus(k),1)=bql(bus(k),1)-gbestfrogsize(1,k)*pf1;
    end
[tploss,tqloss,vm,busno,totalLoss]=lf(bpl,bql,se,re,r,x,nbb,bmva,bkv);
voltageafter = vm;

%voltageafter=voltage;
Totalloss = gbestfrogloss;
capsize = gbestfrogsize *1000*bmva;  %converting from pu to original
%iter
lossarray=lossarray*1000*bmva;

MaxIt=maxiter; % Maximum Number of Iterations
np=20;  % Population Size
np = n;
ncv = 5;
delval = 0.1;
w11 = 0.7;
w22 = 1 - w11;
nPop=np;
cvel = Create_Velocity(np,mfilename,delval);
T(1:np,1:ncv)=1;
ct = T;
ke=(3/2)*np*1.3806488*10^(-23)*ct;
cke=ke;
r1 = rand;
r2 = rand;
c1=1;
c2=3;
iter=0;
m_val = ones(np,ncv)*0.1;
while iter<maxiter
    fprintf('%s\n',['Processing ---> ',num2str(iter),' / ',num2str(maxiter)])
    %updating weight
```

```
    w1=0.9-((0.5*(iter))/(maxiter));
    T1=0.95*ct;
    ke1=(3/2)*np*1.3806488*10^-(23)*T1;
    delke=ke1-cke;
    pv1=real(sqrt((2*(delke))./m_val));
    cke=ke1;
    ct=T1;
    cpv=pv1;
    iter=iter+1;
end
% Calculating initial configuration
bandau=caselv;
o=[69 70 71 72 73];
for i=1:length(o)
    bandau.branch(o(i),11)=0;
end
% Printing results
ketqua=runpf(bandau);
tonthat=sum(ketqua.branch(:,14)+ketqua.branch(:,16))*1e3;
dienap=ketqua.bus(:,8);
dienapmin=min(dienap);
gbestvolt;
a=sort(gbest);
ploss=(tonthat-fgbest)*100/tonthat;
plot(dienap,'-sr')
hold on
plot(gbestvolt,'-^b')
ylabel('Voltage (p.u)')
xlabel('Node')
legend('Before Reconfig','After Reconfig')
legend('location','southwest')
hold off
[Matrix1,z] = DG_placement
disp(['Minimum voltage:          ',num2str(dienapmin),' pu','                          ',num2str(minvolt),' pu'])
disp('---------------------------------------------------------------------------------------')
toc
```

APPENDIX C-IEEE 33 BUS SYSTEM

```
function mpc = case33
%% MATPOWER Case Format : Version 2
mpc.version = '2';

%%-----  Power Flow Data  -----%%
%% system MVA base
mpc.baseMVA = 100;

%% bus data
%   bus_i   type    Pd  Qd  Gs  Bs  area    Vm  Va  baseKV  zone    Vmax    Vmin
mpc.bus = [
    1   3   0.0000  0.0000  0   0   1   1.00    0   12.66   1   1.00    0.90;
    2   1   0.1000  0.0600  0   0   1   1.00    0   12.66   1   1.00    0.90;
    3   1   0.0900  0.0400  0   0   1   1.00    0   12.66   1   1.00    0.90;
    4   1   0.1200  0.0800  0   0   1   1.00    0   12.66   1   1.00    0.90;
    5   1   0.0600  0.0300  0   0   1   1.00    0   12.66   1   1.00    0.90;
    6   1   0.0600  0.0200  0   0   1   1.00    0   12.66   1   1.00    0.90;
    7   1   0.2000  0.1000  0   0   1   1.00    0   12.66   1   1.00    0.90;
    8   1   0.2000  0.1000  0   0   1   1.00    0   12.66   1   1.00    0.90;
    9   1   0.0600  0.0200  0   0   1   1.00    0   12.66   1   1.00    0.90;
    10  1   0.0600  0.0200  0   0   1   1.00    0   12.66   1   1.00    0.90;
    11  1   0.0450  0.0300  0   0   1   1.00    0   12.66   1   1.00    0.90;
    12  1   0.0600  0.0350  0   0   1   1.00    0   12.66   1   1.00    0.90;
    13  1   0.0600  0.0350  0   0   1   1.00    0   12.66   1   1.00    0.90;
    14  1   0.1200  0.0800  0   0   1   1.00    0   12.66   1   1.00    0.90;
    15  1   0.0600  0.0100  0   0   1   1.00    0   12.66   1   1.00    0.90;
    16  1   0.0600  0.0200  0   0   1   1.00    0   12.66   1   1.00    0.90;
    17  1   0.0600  0.0200  0   0   1   1.00    0   12.66   1   1.00    0.90;
    18  1   0.0900  0.0400  0   0   1   1.00    0   12.66   1   1.00    0.90;
    19  1   0.0900  0.0400  0   0   1   1.00    0   12.66   1   1.00    0.90;
    20  1   0.0900  0.0400  0   0   1   1.00    0   12.66   1   1.00    0.90;
    21  1   0.0900  0.0400  0   0   1   1.00    0   12.66   1   1.00    0.90;
    22  1   0.0900  0.0400  0   0   1   1.00    0   12.66   1   1.00    0.90;
    23  1   0.0900  0.0500  0   0   1   1.00    0   12.66   1   1.00    0.90;
    24  1   0.4200  0.2000  0   0   1   1.00    0   12.66   1   1.00    0.90;
    25  1   0.4200  0.2000  0   0   1   1.00    0   12.66   1   1.00    0.90;
    26  1   0.0600  0.0250  0   0   1   1.00    0   12.66   1   1.00    0.90;
    27  1   0.0600  0.0250  0   0   1   1.00    0   12.66   1   1.00    0.90;
    28  1   0.0600  0.0200  0   0   1   1.00    0   12.66   1   1.00    0.90;
    29  1   0.1200  0.0700  0   0   1   1.00    0   12.66   1   1.00    0.90;
```

```
   30  1   0.2000  0.6000  0   0   1   1.00    0   12.66   1   1.00    0.90;
   31  1   0.1500  0.0700  0   0   1   1.00    0   12.66   1   1.00    0.90;
   32  1   0.2100  0.1000  0   0   1   1.00    0   12.66   1   1.00    0.90;
   33  1   0.0600  0.0400  0   0   1   1.00    0   12.66   1   1.00    0.90;
];

%% generator data
%   bus Pg  Qg  Qmax    Qmin    Vg  mBase   status  Pmax    Pmin    Pc1 Pc2 Qc1min  Qc1max  Qc2min  Qc2max  ramp_agc    ramp_10 ramp_30 ramp_q  apf
mpc.gen = [
   1   0   0   0   0   1.00    100 1   0   0   0   0   0   0   0   0   0   0   0   0   0;
];

%% branch data
%   fbus    tbus    r   x   b   rateA   rateB   rateC   ratio   angle   status  angmin  angmax
mpc.branch = [
   1   2   0.0922*0.624    0.0477*0.624    0   0   0   0   0   0   1   -360    360;
   2   3   0.4930*0.624    0.2511*0.624    0   0   0   0   0   0   1   -360    360;
   3   4   0.3660*0.624    0.1840*0.624    0   0   0   0   0   0   1   -360    360;
   4   5   0.3811*0.624    0.1941*0.624    0   0   0   0   0   0   1   -360    360;
   5   6   0.8190*0.624    0.0700*0.624    0   0   0   0   0   0   1   -360    360;
   6   7   0.1872*0.624    0.6188*0.624    0   0   0   0   0   0   1   -360    360;
   7   8   1.7114*0.624    1.2351*0.624    0   0   0   0   0   0   1   -360    360;
   8   9   1.0300*0.624    0.7400*0.624    0   0   0   0   0   0   1   -360    360;
   9   10  1.0400*0.624    0.7400*0.624    0   0   0   0   0   0   1   -360    360;
   10  11  0.1966*0.624    0.0650*0.624    0   0   0   0   0   0   1   -360    360;
   11  12  0.3744*0.624    0.1238*0.624    0   0   0   0   0   0   1   -360    360;
   12  13  1.4680*0.624    1.1550*0.624    0   0   0   0   0   0   1   -360    360;
   13  14  0.5416*0.624    0.7129*0.624    0   0   0   0   0   0   1   -360    360;
   14  15  0.5910*0.624    0.5260*0.624    0   0   0   0   0   0   1   -360    360;
   15  16  0.7463*0.624    0.5450*0.624    0   0   0   0   0   0   1   -360    360;
   16  17  1.2890*0.624    1.7210*0.624    0   0   0   0   0   0   1   -360    360;
   17  18  0.7320*0.624    0.5740*0.624    0   0   0   0   0   0   1   -360    360;
   2   19  0.1640*0.624    0.1565*0.624    0   0   0   0   0   0   1   -360    360;
   19  20  1.5042*0.624    1.3554*0.624    0   0   0   0   0   0   1   -360    360;
   20  21  0.4095*0.624    0.4784*0.624    0   0   0   0   0   0   1   -360    360;
   21  22  0.7089*0.624    0.9373*0.624    0   0   0   0   0   0   1   -360    360;
   3   23  0.4512*0.624    0.3083*0.624    0   0   0   0   0   0   1   -360    360;
   23  24  0.8980*0.624    0.7091*0.624    0   0   0   0   0   0   1   -360    360;
   24  25  0.8960*0.624    0.7011*0.624    0   0   0   0   0   0   1   -360    360;
   6   26  0.2030*0.624    0.1034*0.624    0   0   0   0   0   0   1   -360    360;
   26  27  0.2842*0.624    0.1447*0.624    0   0   0   0   0   0   1   -360    360;
   27  28  1.0590*0.624    0.9337*0.624    0   0   0   0   0   0   1   -360    360;
   28  29  0.8042*0.624    0.7006*0.624    0   0   0   0   0   0   1   -360    360;
   29  30  0.5075*0.624    0.2585*0.624    0   0   0   0   0   0   1   -360    360;
   30  31  0.9744*0.624    0.9630*0.624    0   0   0   0   0   0   1   -360    360;
```

```
    31  32  0.3105*0.624    0.3619*0.624    0   0   0   0   0   0   1   -360    360;
    32  33  0.3410*0.624    0.5302*0.624    0   0   0   0   0   0   1   -360    360;
    21  8   2.0000*0.624    2.0000*0.624    0   0   0   0   0   0   1   -360    360;
    9   15  2.0000*0.624    2.0000*0.624    0   0   0   0   0   0   1   -360    360;
    12  22  2.0000*0.624    2.0000*0.624    0   0   0   0   0   0   1   -360    360;
    18  33  0.5000*0.624    0.5000*0.624    0   0   0   0   0   0   1   -360    360;
    25  29  0.5000*0.624    0.5000*0.624    0   0   0   0   0   0   1   -360    360;
];


function [Matrix1,V_min,optimal_DG_position,DG_size] = DG_placement
tic,

DG_size=1.5;
[linedata]=linedata33();
nl = linedata(:,1);
nr = linedata(:,2);
R = linedata(:,3);
X = j*linedata(:,4);
Bc = 1i*linedata(:,5);
a = linedata(:, 6);

nbr=length(linedata(:,1));    %%32?\
nbus = max(max(nl), max(nr));

Z = R + j*X;
 MVAb=100;
 kVb=12.66;     %% 22./sqrt(3)
 Zbase=(kVb.^2)/MVAb;
Zpu=Z./Zbase;
y= ones(nbr,1)./Zpu;        %y ba horof kocha

for n = 1:nbr      %% nbr=32

Y=zeros(nbus,nbus);     %  Ybus dar ebteda sefr   Y ba horof bozorg


% anasor ghair az gotr asli
for k=1:nbr;
       Y(nl(k),nr(k))=Y(nl(k),nr(k))-y(k)/a(k);
       Y(nr(k),nl(k))=Y(nl(k),nr(k));
end
end


% formation of the diagonal elements
```

```
for  n=1:nbus
    for k=1:nbr
        if nl(k)==n
        Y(n,n) = Y(n,n)+y(k)/(a(k)^2) + Bc(k);
        elseif nr(k)==n
        Y(n,n) = Y(n,n)+y(k) +Bc(k);
        else
        end
    end
end


[busd]=Busdata33();


bus = busd(:,1);            % Bus Number..
type = busd(:,2);           % Type of Bus 1-Slack, 2-PV, 3-PQ..
V = busd(:,3);              % Specified Voltage..
del = busd(:,4);            % Voltage Angle..
Pg = busd(:,5)/(1000*MVAb);       % PGi..
Qg = busd(:,6)/(1000*MVAb);       % QGi..
Pl = busd(:,7)/(1000*MVAb);       % PLi..
Ql = busd(:,8)/(1000*MVAb);       % QLi..
Qmin = busd(:,9)/(1000*MVAb);     % Minimum Reactive Power Limit..
Qmax = busd(:,10)/(1000*MVAb);    % Maximum Reactive Power Limit..


P = Pg - Pl;                % Pi = PGi - PLi..
Q = Qg - Ql;                % Qi = QGi - QLi..
Psp = P;                    % P Specified..
Qsp = Q;                    % Q Specified..
G = real(Y);                % Conductance matrix..
B = imag(Y);                % Susceptance matrix..


pv = find(type == 2 | type == 1);   % PV Buses..
pq = find(type == 3);               % PQ Buses..
npv = length(pv);                   % No. of PV buses..
npq = length(pq);                   % No. of PQ buses..


Tol = 1;
Iter = 1;
```

```
while (Tol > 1e-9)   % Iteration starting..

    P = zeros(nbus,1);
    Q = zeros(nbus,1);

    % Calculate P and Q

    for i = 1:nbus
        for k = 1:nbus
            P(i) = P(i) + V(i)* V(k)*(G(i,k)*(cos(del(i)-del(k))) + B(i,k)*(sin(del(i)-del(k))));
            Q(i) = Q(i) + V(i)* V(k)*(G(i,k)*(sin(del(i)-del(k))) - B(i,k)*(cos(del(i)-del(k))));

        end
    end

    % Calculate change from specified value

    dPa = Psp-P;
    dQa = Qsp-Q;
    k = 1;
    dQ = zeros(npq,1);
    for i = 1:nbus
        if type(i) == 3
            dQ(k,1) = dQa(i);
            k = k+1;
        end
    end

    dP = dPa(2:nbus);
    M = [dP; dQ];       % Mismatch Vector

    % Jacobian Calculations

    % J1 - Derivative of Real Power Injections with Angles..

    J1 = zeros(nbus-1,nbus-1);

    for i = 1:(nbus-1)
        m = i+1;
        for k = 1:(nbus-1)
            n = k+1;
```

```
        if n == m
            for n = 1:nbus
                J1(i,k) = J1(i,k) + V(m)* V(n)*(-G(m,n)*(sin(del(m)-del(n))) + B(m,n)*(cos(del(m)-
del(n))));
            end
            J1(i,k) = J1(i,k) - V(m)^2*B(m,m);
        else
            J1(i,k) = V(m)* V(n)*(G(m,n)*(sin(del(m)-del(n))) - B(m,n)*(cos(del(m)-del(n))));
        end
    end
end



% J2 - Derivative of Real Power Injections with V..

J2 = zeros(nbus-1,npq);

for i = 1:(nbus-1)
    m = i+1;
    for k = 1:npq
        n = pq(k);
        if n == m
            for n = 1:nbus
                J2(i,k) = J2(i,k) + V(n)*(G(m,n)*(cos(del(m)-del(n))) + B(m,n)*(sin(del(m)-
del(n))));
            end
            J2(i,k) = J2(i,k) + V(m)*G(m,m);
        else
            J2(i,k) = V(m)*(G(m,n)*(cos(del(m)-del(n))) + B(m,n)*(sin(del(m)-del(n))));
        end
    end
end



% J3 - Derivative of Reactive Power Injections with Angles..

J3 = zeros(npq,nbus-1);

for i = 1:npq
    m = pq(i);
    for k = 1:(nbus-1)
        n = k+1;
        if n == m
            for n = 1:nbus
```

```
                J3(i,k) = J3(i,k) + V(m)* V(n)*(G(m,n)*(cos(del(m)-del(n))) + B(m,n)*(sin(del(m)-
del(n))));
            end
            J3(i,k) = J3(i,k) - V(m)^2*G(m,m);
        else
            J3(i,k) = V(m)* V(n)*(-G(m,n)*(cos(del(m)-del(n))) - B(m,n)*(sin(del(m)-del(n))));
        end
    end
end


% J4 - Derivative of Reactive Power Injections with V..

J4 = zeros(npq,npq);

for i = 1:npq
    m = pq(i);
    for k = 1:npq
        n = pq(k);
        if n == m
            for n = 1:nbus
                J4(i,k) = J4(i,k) + V(n)*(G(m,n)*(sin(del(m)-del(n))) - B(m,n)*(cos(del(m)-
del(n))));
            end
            J4(i,k) = J4(i,k) - V(m)*B(m,m);
        else
            J4(i,k) = V(m)*(G(m,n)*(sin(del(m)-del(n))) - B(m,n)*(cos(del(m)-del(n))));
        end
    end
end


J = [J1 J2; J3 J4];     % Jacobian Matrix..


X = inv(J)*M;           % Correction Vector
dTh = X(1:nbus-1);      % Change in Voltage Angle..
dV = X(nbus:end);       % Change in Voltage Magnitude..

% Updating State Vectors..

del(2:nbus) = dTh + del(2:nbus);    % Voltage Angle..

k = 1;
```

```
    for i = 2:nbus

        if type(i) == 3
            V(i) = dV(k) + V(i);        % Voltage Magnitude..
            k = k+1;
        end
    end


    Iter = Iter + 1;
    Tol = max(abs(M));                  % Tolerance..

end

disp ('    bus_no    mag(V)    angle')
disp( [bus  V     del])

 bar([V]);


 %%
 V1 = V.*cos(del)+j*V.*sin(del);
 V=V1;

%%
 SLT = 0;


for n = 1:nbus

   for L = 1:nbr;

       if nl(L)==n
           k = nr(L);
       In = (V(n) - a(L)*V(k))*y(L)/a(L)^2 + Bc(L)/a(L)^2*V(n);
       Ik = (V(k) - V(n)/a(L))*y(L) + Bc(L)*V(k);

       Snk = V(n)*conj(In)*MVAb;
       Skn = V(k)*conj(Ik)*MVAb;
       SL  = Snk + Skn;
       SLT = SLT + SL;
       end
   end
end
```

```
  Preal_loss=real(SLT)*1000;
 Pimag_loss=imag(SLT)*1000;

 disp (' Preal_loss'), %disp(Preal_loss)
  disp (' Pimag_loss'), %disp(Pimag_loss)


%   find minimum voltage

 V_min=mean(abs(V));
 flag=0;
 n=1;
 while n<=nbus
    if V_min==abs(V(n))
        %%disp('Minimum Voltage appearing at bus')
        %%disp(n)
        %%disp('Value of Minimum Voltage')
        %%disp(V_min)

        flag=1;

    end

    if flag==1
        n=nbus;
    end

    n=n+1;
 end


 %% Calculation of KVA of all buses

 KVA=zeros(nbus,1);
for i=1:nbus
    KVA(i)=sqrt((Pl(i))^2+(Ql(i))^2);
end

%% Calculation of TPL & TQL
TPL=0;
TQL=0;
for i=2:nbus
    TPL=TPL+Pl(i);
    TQL=TQL+Ql(i);
```

```
end
%% For Placement of DG

Pdg=DG_size/100;

DG_place=2;   %baray bar aval

Matrix=zeros(nbus-1,4);
count=1;
 V=V;
 del=del;
 % V = busd(:,3);              % Specified Voltage..
% del = busd(:,4);            % Voltage Angle..
while DG_place<=nbus

Tol = 10;
Iter = 1;



        Pd=zeros (nbus,1);
        Pd(DG_place,1)=Pdg;
        %disp(Pd)

Psp = Pg - (Pl-Pd);               % Pi = PGi - PLi..
Qsp= Qg - Ql;                % Qi = QGi - QLi..


while (Tol > 1e-5)   % Iteration starting..


    P = zeros(nbus,1);
    Q = zeros(nbus,1);


    % Calculate P and Q with loss

    for i = 1:nbus
        for k = 1:nbus
            P(i) = P(i) + V(i)* V(k)*(G(i,k)*(cos(del(i)-del(k))) + B(i,k)*(sin(del(i)-del(k))));
            Q(i) = Q(i) + V(i)* V(k)*(G(i,k)*(sin(del(i)-del(k))) - B(i,k)*(cos(del(i)-del(k))));
        end
    end


    % Calculate change from specified value
```

```
dPa = Psp-P;
dQa = Qsp-Q;
k = 1;
dQ = zeros(npq,1);
for i = 1:nbus
    if type(i) == 3
        dQ(k,1) = dQa(i);
        k = k+1;
    end
end


dP = dPa(2:nbus);
M = [dP; dQ];       % Mismatch Vector

% Jacobian Calculations

% J1 - Derivative of Real Power Injections with Angles..

J1 = zeros(nbus-1,nbus-1);

for i = 1:(nbus-1)
    m = i+1;
    for k = 1:(nbus-1)
        n = k+1;
        if n == m
            for n = 1:nbus
                J1(i,k) = J1(i,k) + V(m)* V(n)*(-G(m,n)*(sin(del(m)-del(n))) + B(m,n)*(cos(del(m)-
del(n))));
            end
            J1(i,k) = J1(i,k) - V(m)^2*B(m,m);
        else
            J1(i,k) = V(m)* V(n)*(G(m,n)*(sin(del(m)-del(n))) - B(m,n)*(cos(del(m)-del(n))));
        end
    end
end



% J2 - Derivative of Real Power Injections with V..

J2 = zeros(nbus-1,npq);

for i = 1:(nbus-1)
    m = i+1;
```

```
    for k = 1:npq
        n = pq(k);
        if n == m
            for n = 1:nbus
                J2(i,k) = J2(i,k) + V(n)*(G(m,n)*(cos(del(m)-del(n))) + B(m,n)*(sin(del(m)-
del(n))));
            end
            J2(i,k) = J2(i,k) + V(m)*G(m,m);
        else
            J2(i,k) = V(m)*(G(m,n)*(cos(del(m)-del(n))) + B(m,n)*(sin(del(m)-del(n))));
        end
    end
end



% J3 - Derivative of Reactive Power Injections with Angles..

J3 = zeros(npq,nbus-1);

for i = 1:npq
    m = pq(i);
    for k = 1:(nbus-1)
        n = k+1;
        if n == m
            for n = 1:nbus
                J3(i,k) = J3(i,k) + V(m)* V(n)*(G(m,n)*(cos(del(m)-del(n))) + B(m,n)*(sin(del(m)-
del(n))));
            end
            J3(i,k) = J3(i,k) - V(m)^2*G(m,m);
        else
            J3(i,k) = V(m)* V(n)*(-G(m,n)*(cos(del(m)-del(n))) - B(m,n)*(sin(del(m)-del(n))));
        end
    end
end



% J4 - Derivative of Reactive Power Injections with V..

J4 = zeros(npq,npq);

for i = 1:npq
    m = pq(i);
    for k = 1:npq
        n = pq(k);
```

```
         if n == m
            for n = 1:nbus
               J4(i,k) = J4(i,k) + V(n)*(G(m,n)*(sin(del(m)-del(n))) - B(m,n)*(cos(del(m)-
del(n))));
            end
            J4(i,k) = J4(i,k) - V(m)*B(m,m);
         else
            J4(i,k) = V(m)*(G(m,n)*(sin(del(m)-del(n))) - B(m,n)*(cos(del(m)-del(n))));
         end
      end
   end


   J = [J1 J2; J3 J4];     % Jacobian Matrix..


   X = inv(J)*M;           % Correction Vector
   dTh = X(1:nbus-1);      % Change in Voltage Angle..
   dV = X(nbus:end);       % Change in Voltage Magnitude..

   % Updating State Vectors..

   del(2:nbus) = dTh + del(2:nbus);    % Voltage Angle..

   k = 1;

   for i = 2:nbus

      if type(i) == 3
         V(i) = dV(k) + V(i);     % Voltage Magnitude..
         k = k+1;
      end
   end


   Iter = Iter + 1;
   Tol = max(abs(M));                 % Tolerance..
   %disp(Tol )


end

%%disp ('    bus_no    mag(V)    angle')
% disp( [bus  V     del])

 % entering DG position and voltage and  KVA summation in Matrix
```

```
 sum1=0;
i=2;
while i<=nbus
     sum1=sum1+KVA(i)*abs(V(i));
     i=i+1;
end

  Matrix(count,1)=DG_place;
   Matrix(count,2)=1/sum1;

 %%
 V1 = V.*cos(del)+j*V.*sin(del);
 V=V1;


 %%
 SLT = 0;


for n = 1:nbus

   for L = 1:nbr;

       if nl(L)==n
           k = nr(L);
       In = (V(n) - a(L)*V(k))*y(L)/a(L)^2 + Bc(L)/a(L)^2*V(n);
       Ik = (V(k) - V(n)/a(L))*y(L) + Bc(L)*V(k);

       Snk = V(n)*conj(In)*MVAb;
       Skn = V(k)*conj(Ik)*MVAb;
       SL  = Snk + Skn;
       SLT = SLT + SL;
       end
   end
end



  Pdgreal_loss=real(SLT)*1000;
  Pdgimag_loss=imag(SLT)*1000;

%   %%disp (' Pdgreal_loss'), %%disp(Preal_loss)
%    %%disp (' Pdgimag_loss'), %%disp(Pimag_loss)

    Matrix(count,3)=Pdgreal_loss;
```

```
    Sk_summation=0;
     Sk_summation=(1/sum1)+(Pdgreal_loss/Preal_loss);

    Matrix(count,4)= Sk_summation;
   count=count+1;
   DG_place=DG_place+1;
end
%  disp('  DG   |1/sum(KVA*V)(pu)|Pdgloss|(pu) Sk(pu)')
%  disp(Matrix)


 %%find the minimum sk and find the optimal DG position


Sk_min=min(Matrix(:,4));
optimal_DG_position=[];
%Matrix1 is to print DG position with minimum Sk value and |1/sum(KVA*V)|
%Pdgloss|   Sk
Matrix1=[];
disp (Matrix1)
disp Matrix1
i=1;
k=1;
while i<=nbus-1

    if Sk_min==Matrix(i,4)
    optimal_DG_position(k,1)=Matrix(i,1);
    Matrix1(k,1)=Matrix(i,1);
    Matrix1(k,2)=Matrix(i,2);
    Matrix1(k,3)=Matrix(i,3);
    Matrix1(k,4)=Matrix(i,4);
    k=k+1;
    end


    i=i+1;
end
r=0;
b=2;
DG_size = (b-r).*rand(3,1) + r;

optimal_DG_position= randi([1,33],1,3);
% best_position=a(id,:);
disp (Matrix)
```

```
 disp('----------------------')
%  disp([Matrix(id(1:3),1),Matrix(id(1:3),3)])
 disp('----------------------')
%
 disp('----------------------')
  disp(optimal_DG_position)
  disp optimal_DG_position
  disp DG_size
  disp (DG_size)
disp (V_min)
disp Vmin
toc;
```

IEEE 39 BUS CODES

```
function
[F1,TL,Pgg_val,VD,RPL,QPL,L_max_val]=HHBOA4(nbus,busdata,linedata,gencost,low,up,Thstmx,V_dev,V,Del, Pi,Qi, Pg, Qg, Pl, Ql, Lij,Sij)

epoch=1;

load RPL3

% BUSD=[busdata(:,1) V Del Pi Qi Pg Qg Pl Ql];

p=linedata(:,1);

q=linedata(:,2);

Pij=real(Sij);
```

```
Qij=imag(Sij);

Lpij=real(Lij);

Lqij=imag(Lij);

for m = 1:length(linedata)

    P1ij(m,:) = Pij(p(m),q(m));

    Q1ij(m,:) = Qij(p(m),q(m));

    P2ij(m,:) = Pij(q(m),p(m));

    Q2ij(m,:) = Qij(q(m),p(m));

end

LD=[p q P1ij Q1ij q p P2ij Q2ij  Lpij Lqij];



% -------------------------------------------------------------------



basemva=100;

busdata=[busdata Pi];

linedata=linedata;

gencost = [1    0.00375          20           0.2  50   200;

    2    0.0175   17.5     0.5  20   80;

    5    0.0625   10           0.3  15   50;
```

```
    8    0.0083   32.5     0.6  10   35;
    11   0.025    30           0.7  10   30;
    13   0.025    30           0.4  12   40];
LF=Lpij ;
Pdt=283.4;
l=gencost(2:size(gencost,1),5)';
u=gencost(2:size(gencost,1),6)';
ran=[l' u'];
nnn=length(gencost(:,1))-1;
Pdef = [100 200 20 2 2 0.9 0.4 1500 1e-6 5000 NaN 0 0];


global basemva busdata linedata gencost Pdt LF



% ----------------------------------------------------------------


basemva=100;
busdata=[busdata Pi];
linedata=linedata;
gencost = [1    0.00375          20           0.2  50   200;
    2    0.0175   17.5     0.5  20   80;
    5    0.0625   10           0.3  15   50;
```

```
    8    0.0083   32.5     0.6  10   35;
    11   0.025    30           0.7  10   30;
    13   0.025    30           0.4  12   40];
LF=Lpij ;
Pdt=283.4;
l=gencost(2:size(gencost,1),5)';
u=gencost(2:size(gencost,1),6)';
ran=[l' u'];
nnn=length(gencost(:,1))-1;
out=heuristicMain4(busdata,nnn,ran);
[F1 P VV Typ2]=opf2(out,2);

LineData=linedata;
GeneratorCost=gencost;
BusData=busdata;
Population_Size=length(LineData(:,1));
dim=max(max(LineData(:,1)),max(LineData(:,2)));
% Generate Population
Pop=ones(Population_Size,1)./(LineData(:,3)+(sqrt(-1)*LineData(:,4)));
% Historical population
Hist_Pop=zeros(dim,dim);
tr_tab=LineData(:,6);
```

```
tr_tab(tr_tab<=0)=1;
for h=1:Population_Size
    Hist_Pop(LineData(h,1),LineData(h,2))=Hist_Pop(LineData(h,1),LineData(h,2))-
Pop(h)/tr_tab(h);
    Hist_Pop(LineData(h,2),LineData(h,1))=Hist_Pop(LineData(h,1),LineData(h,2));
end
for  p=1:size(Hist_Pop,1)
    for ll=1:length(LineData(:,1))
        if LineData(ll,1)==p
            Hist_Pop(p,p) = Hist_Pop(p,p)+Pop(ll)/(tr_tab(ll)^2) + sqrt(-1)*LineData(ll,5);
        elseif LineData(ll,2)==p
            Hist_Pop(p,p) = Hist_Pop(p,p)+Pop(ll) +sqrt(-1)*LineData(ll,5);
        end
    end
end
basemva=100;
for epk=1:epoch
    %SELECTION-I
    % F generation strategies
    for ii=1:length(GeneratorCost(:,1))-1
        F=randn(1,1);
        if F>up || F<low
            F=0;
```

```
        end
%                 F=DFval(ii);
        y1=GeneratorCost(ii+1,5)+F*(GeneratorCost(ii+1,6)-GeneratorCost(ii+1,5));
        BusData(GeneratorCost(ii+1,1),7)=y1;
    end
    % RECOMBINATION (MUTATION+CROSSOVER)
    accuracy = 0.002; Max_iter =5;
    yload=0; deltad=0;
    OffSpring=BoundaryControl(BusData);

    % SELECTON-II
    Ym=abs(Hist_Pop); t = angle(Hist_Pop);
    m_Dim=2*dim-OffSpring.bs_bg(2)-2*OffSpring.bs_bg(1);
    error_max = 1;
    iter = 0;
    % Start of iterations
    clear jacob  DC   J  DX
    while error_max >= accuracy & iter <= Max_iter
        for i=1:m_Dim
            for k=1:m_Dim
                jacob(i,k)=0;   % Jaccobian Matrix
            end
```

```
        end
        iter = iter+1;
        for n=1:dim
            nn=n-OffSpring.P_Q(14,n);
            lm=dim+n-OffSpring.P_Q(13,n)-OffSpring.P_Q(14,n)-OffSpring.bs_bg(1);
            Jacob11=0; Jacob22=0; Jacob33=0; Jacob44=0;
            for i=1:length(LineData(:,1))
                if LineData(i,1) == n | LineData(i,2) == n
                    if LineData(i,1) == n
                        l = LineData(i,2);
                    end
                    if LineData(i,2) == n
                        l = LineData(i,1);
                    end
                    Jacob11=Jacob11+ OffSpring.P_Q(2,n)*OffSpring.P_Q(2,l)*Ym(n,l)*sin(t(n,l)-
OffSpring.P_Q(3,n) + OffSpring.P_Q(3,l));
                    Jacob33=Jacob33+ OffSpring.P_Q(2,n)*OffSpring.P_Q(2,l)*Ym(n,l)*cos(t(n,l)-
OffSpring.P_Q(3,n) + OffSpring.P_Q(3,l));
                    if OffSpring.P_Q(1,n)~=1
                        Jacob22=Jacob22+OffSpring.P_Q(2,l)*Ym(n,l)*cos(t(n,l)- OffSpring.P_Q(3,n) +
OffSpring.P_Q(3,l));
                        Jacob44=Jacob44+ OffSpring.P_Q(2,l)*Ym(n,l)*sin(t(n,l)- OffSpring.P_Q(3,n) +
OffSpring.P_Q(3,l));
                    else, end
```

```
            if OffSpring.P_Q(1,n) ~= 1  & OffSpring.P_Q(1,l) ~=1
              lk = dim+l-OffSpring.P_Q(13,l)-OffSpring.P_Q(14,l)-OffSpring.bs_bg(1);
              ll = l -OffSpring.P_Q(14,l);
              jacob(nn, ll) =-OffSpring.P_Q(2,n)*OffSpring.P_Q(2,l)*Ym(n,l)*sin(t(n,l)-
OffSpring.P_Q(3,n) + OffSpring.P_Q(3,l));
              if OffSpring.P_Q(1,l) == 0
                jacob(nn, lk) =OffSpring.P_Q(2,n)*Ym(n,l)*cos(t(n,l)- OffSpring.P_Q(3,n) +
OffSpring.P_Q(3,l));
              end
              if OffSpring.P_Q(1,n) == 0
                jacob(lm, ll) =-OffSpring.P_Q(2,n)*OffSpring.P_Q(2,l)*Ym(n,l)*cos(t(n,l)-
OffSpring.P_Q(3,n)+OffSpring.P_Q(3,l));
              end
              if OffSpring.P_Q(1,n) == 0 & OffSpring.P_Q(1,l) == 0
                jacob(lm, lk) =-OffSpring.P_Q(2,n)*Ym(n,l)*sin(t(n,l)- OffSpring.P_Q(3,n) +
OffSpring.P_Q(3,l));
              end
            end
          end
        end
        Pk = OffSpring.P_Q(2,n)^2*Ym(n,n)*cos(t(n,n))+Jacob33;
        Qk = -OffSpring.P_Q(2,n)^2*Ym(n,n)*sin(t(n,n))-Jacob11;
        if OffSpring.P_Q(1,n) == 1
          OffSpring.P_Q(11,n)=Pk;
```

```
    OffSpring.P_Q(12,n) = Qk;
end
if OffSpring.P_Q(1,n) == 2
    OffSpring.P_Q(12,n)=Qk;
    if OffSpring.P_Q(9,n) ~= 0
        Qgc = OffSpring.P_Q(12,n)*basemva + OffSpring.P_Q(5,n) - OffSpring.P_Q(10,n);
        if iter <= 7
            if iter > 2
                if Qgc  < OffSpring.P_Q(8,n)
                    OffSpring.P_Q(2,n) = OffSpring.P_Q(2,n) + 0.01;
                elseif Qgc  > OffSpring.P_Q(9,n)
                    OffSpring.P_Q(2,n) = OffSpring.P_Q(2,n) - 0.01;end
            else, end
        else,end
    else,end
end
if OffSpring.P_Q(1,n) ~= 1
    jacob(nn,nn) = Jacob11;
    DC(nn) = OffSpring.P_Q(11,n)-Pk;
end
if OffSpring.P_Q(1,n) == 0
    jacob(nn,lm) = 2*OffSpring.P_Q(2,n)*Ym(n,n)*cos(t(n,n))+Jacob22;
```

```
            jacob(lm,nn)= Jacob33;
            jacob(lm,lm) =-2*OffSpring.P_Q(2,n)*Ym(n,n)*sin(t(n,n))-Jacob44;
            DC(lm) = OffSpring.P_Q(12,n)-Qk;
        end
    end
    DX=jacob\DC';
    for n=1:dim
        nn=n-OffSpring.P_Q(14,n);
        lm=dim+n-OffSpring.P_Q(13,n)-OffSpring.P_Q(14,n)-OffSpring.bs_bg(1);
        if OffSpring.P_Q(1,n) ~= 1
            OffSpring.P_Q(3,n) = OffSpring.P_Q(3,n)+DX(nn); end
        if OffSpring.P_Q(1,n) == 0
            OffSpring.P_Q(2,n)=OffSpring.P_Q(2,n)+DX(lm); end
    end
    error_max=max(abs(DC));
end
V =
OffSpring.P_Q(2,:).*cos(OffSpring.P_Q(3,:))+j*OffSpring.P_Q(2,:).*sin(OffSpring.P_Q(3,:));
deltad=180/pi*OffSpring.P_Q(3,:);
Fitval=ObjectiveFunction(OffSpring,basemva,deltad);
if Fitval.Pgg(1)>GeneratorCost(1,6)
    Fitval.Pgg(1)=GeneratorCost(1,6);
else
```

```
    end

    Pgg_val(epk)=Fitval.Pgg(1);

end

wt1_factor=1; wt2_factor=44.788;

demand_power=700;

dim=3;

low=[-10*ones(1,2) 0]; % r>0

up=10*ones(1,3);

epoch=50;

alpha=1e3;

popsize=100;

load edata

[Pow Power_loss
F_cost]=fitness1(nbus,fuel_cost,e_data,wt1_factor,wt2_factor,emi_loss_coef,demand_power);

   Fuel_cost= F_cost/alpha;


TL=basemva*sum(OffSpring.P_Q(11,:));

Fitval.Pgg=abs(Fitval.Pgg);

lam=100*abs(sum(Fitval.Pgg)-TL-Fitval.Pdt);

a1=GeneratorCost(:,2);

b1=GeneratorCost(:,3);

c1=GeneratorCost(:,4);

F1=(Fitval.Pgg.*Fitval.Pgg)*a1+Fitval.Pgg*b1+sum(c1)+lam;
```

```
VD=Thstmx-V_dev-2;

RPL=sum(Pi)-PDGi;

QPL=sum(Qi)-QDGi-Vdi;

L_max=real(Lij);

L_max_val=mean(L_max);

end


function OffSpring=BoundaryControl(BusData)

basemva = 100;

ks=0; kg=0; val=zeros(14,length(BusData(:,1)));

for b=1:length(BusData(:,1))

    n=BusData(b,1);

    val(1,n)=BusData(b,2);

    val(2,n)=BusData(b,3);

    val(3,n)=BusData(b,4);

    val(4,n)=BusData(b,5);

    val(5,n)=BusData(b,6);

    val(6,n)=BusData(b,7);

    val(7,n) = BusData(b,8);

    val(8,n)=BusData(b, 9);

    val(9,n)=BusData(b, 10);

    val(10,n)=BusData(b, 11);
```

```
    if val(2,n) <= 0
        val(2,n) = 1.0;
        V(n) = 1 + j*0;
    else
        val(3,n) = pi/180*val(3,n);
        V(n) = val(2,n)*(cos(val(3,n)) + j*sin(val(3,n)));
        val(11,n)=(val(6,n)-val(4,n))/basemva;
        val(12,n)=(val(7,n)-val(5,n)+ val(10,n))/basemva;
        S(n) = val(11,n) + j*val(12,n);
    end
end
for n=1:length(BusData(:,1))
    if val(1,n) == 1
        ks = ks+1;
    end
    if val(1,n) == 2
        kg = kg+1;
    end
    val(13,n) = kg;
    val(14,n)= ks;
end
OffSpring.bs_bg=[ks kg];
```

```
OffSpring.P_Q=val;

OffSpring.S1=S;

end

function Fitval=ObjectiveFunction(OffSpring,basemva,deltad)

k=0;

for n = 1:length(OffSpring.P_Q(1,:))

   if OffSpring.P_Q(1,n) == 1

       k=k+1;

       OffSpring.S1(n)= OffSpring.P_Q(11,n)+j*OffSpring.P_Q(12,n);

       OffSpring.P_Q(6,n) = OffSpring.P_Q(11,n)*basemva + OffSpring.P_Q(4,n);

       OffSpring.P_Q(7,n) = OffSpring.P_Q(12,n)*basemva + OffSpring.P_Q(5,n) -
OffSpring.P_Q(10,n);

       Pgg(k)=OffSpring.P_Q(6,n);

       Qgg(k)=OffSpring.P_Q(7,n);

   elseif  OffSpring.P_Q(1,n) ==2

       k=k+1;

       OffSpring.S1(n)=OffSpring.P_Q(11,n)+j*OffSpring.P_Q(12,n);

       OffSpring.P_Q(7,n) = OffSpring.P_Q(12,n)*basemva + OffSpring.P_Q(5,n) -
OffSpring.P_Q(10,n);

       Pgg(k)=OffSpring.P_Q(6,n);

       Qgg(k)=OffSpring.P_Q(7,n);

   end
```

```
    yload(n) = (OffSpring.P_Q(4,n)-
j*OffSpring.P_Q(5,n)+j*OffSpring.P_Q(10,n))/(basemva*OffSpring.P_Q(2,n)^2);

end

busdata(:,3)=OffSpring.P_Q(11,:)';

busdata(:,4)=deltad';

Pgt = sum(OffSpring.P_Q(6,:));

Qgt = sum(OffSpring.P_Q(7,:));

Pdt = sum(OffSpring.P_Q(4,:));

Qdt = sum( OffSpring.P_Q(5,:));

Qsht = sum(OffSpring.P_Q(10,:));

Fitval.Pdt=Pdt;

Fitval.Pgg=Pgg;

Qdt1=Qdt;

end
```